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SUSTAINABLE URBANIZATION AND GREEN TOTAL FACTOR PRODUCTIVITY: EVIDENCE FROM CHINA'S NEW-TYPE URBANIZATION PLAN

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Abstract. Sustainable urbanization is significant in developing countries. This paper studies whether Chinese-type sustainable urbanization, that is new-type urbanization, promotes green total factor productivity (GTFP). We find that the new-type urbanization implementation in China, on average, significantly promotes GTFP by 3.2%. The positive effect of new-type urbanization on GTFP is correlated with promoting innovation, especially green innovation, and improving allocation efficiency. We do not find clear evidence for industrial upgrading, including industrial advancement and rationalization. This is because industrial upgrading is a gradual process and cannot be achieved shortly. Instead, we find that pilot cities might screen the entry of new firms and keep polluting firms out comparatively. The heterogeneous results indicate that the promotion effects on GTFP are more salient in regions with strong environmental regulation and adequate factor endowments. We have some practical implications for sustainable development in developing countries.

Keywords: sustainable urbanization, green total factor productivity, innovation promoting, industrial upgrading.

JEL Classification: O18, O21, O47.

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1. Introduction

Recent decades have seen rapid urbanization in developing countries (Henderson, 2002; NBS, 2020). However, compared with developed countries urbanized at a gradual pace, developing countries face more significant challenges arising from lagged political institutions, inefficient market instruments, and urban-biased policies (Henderson, 2002). Specific to the largest developing country, China has experienced unprecedented rural-to-urban migration and an enormous expansion of urban scale in a short time (see Figure 1), which results in substantial undesirable externalities and is gradually unsustainable (Bertinelli & Black, 2004; Li et al., 2016; Xu & Yang, 2022). Realizing the impediments of traditional urbanization to economic growth, the central government implements a sustainable urbanization strategy (the National New-type Urbanization Plan 2014–2020, thereafter the NUP) and attempts to facilitate the

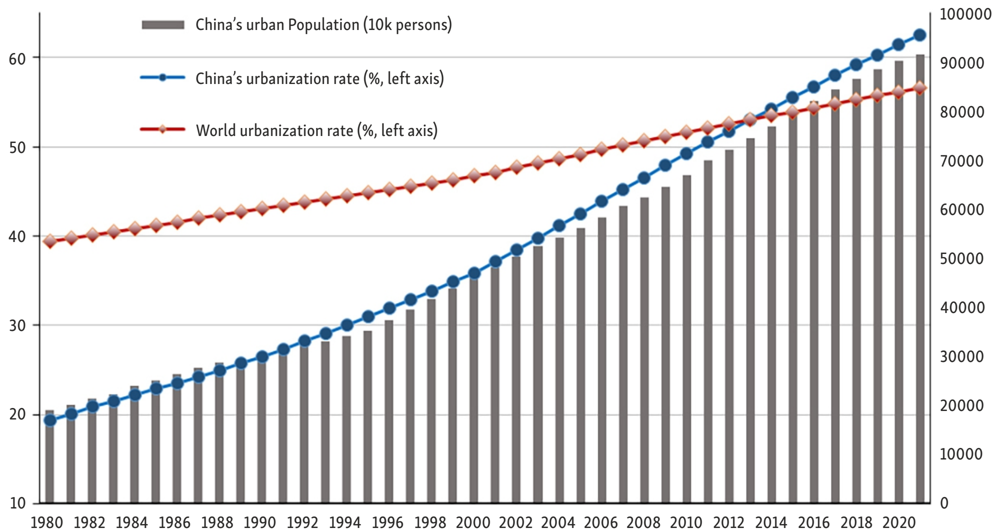


Figure 1. China's rapid urbanization and the comparison with the world average

green and sustainable transformation of urban China. Does China's sustainable urbanization enhance economic growth quality? This issue holds immense importance for developing nations as they strive for sustainable urbanization with large populations (Wang et al., 2019).

Comparatively, the NUP is people-centered rather than land-centered and covers the social, economic, environmental, and institutional aspects of sustainability during the process of urbanization (Guan et al., 2018; Tan et al., 2016). According to the construction guidelines, the NUP focuses on advancing urban intelligent, intensive, green, and low-carbon development.[1] For example, the NUP sets up strict conditions for urban renewal and reconstruction, subject to population density, output intensity, and environmental carrying capacity. Meanwhile, the policy encourages pilot cities to explore more efficient administrative systems and governance structures (e.g., strengthening the power of towns) to suit local economic development. Besides, local governments are required to remove barriers to rural-to-urban migration and promote the full coverage of public services for residents, which facilitates labor mobility and stimulates economic potential. Through these meaningful explorations, the NUP is perceived to advance urban sustainable development and pioneers the path of modernization with Chinese characteristics (e.g., huge population size, common prosperity, and green development).

To estimate the impact of such a sustainable urbanization strategy on economic growth quality, we first employ green total factor productivity (GTFP) as a measure of economic growth quality. Compared to the total factor productivity (TFP) measure, GTFP considers resource and environmental constraints and is a more comprehensive and representative indicator measuring an economy's green and sustainable development (Chen & Golley, 2014; Xia & Xu, 2020). Second, we take the NUP enacted in China as a quasi-natural experiment. Leveraging the within-city variation, we employ a staggered difference-in-differences (DID) approach to quantify the impact of sustainable urbanization.

[1] According to the NUP, ecology should be incorporated throughout the urbanization process, with a particular emphasis on the intelligent, intensive, low-carbon and green development.

To remove the influence of the 2008 financial crisis as well as the outbreak of COVID-19, we choose panel data spanning from 2009 to 2018. By compiling several sources of data, we find that the NUP has a significantly positive effect on GTFP. After controlling for the covariates and two-way fixed effects, we show that the NUP improves GTFP by 3.2% comparatively. The promotion is robust to a battery of alternative specifications. From the influencing mechanisms, we find that the NUP might improve GTFP through promoting innovation and improving allocation efficiency. However, our estimated results do not support the industrial upgrading hypothesis, i.e., promoting the advancement and rationalization of industrial structure. Instead, using the micro-level firm registration data, we find that pilot cities might increase the entry costs of polluting firms and thus have a screening effect on firm entry. Besides, we also examine the heterogeneous effects of the NUP on GTFP and find that the promotion effects on GTFP are more salient in regions with stringent environmental regulation, adequate human capital, sufficient fiscal support, and a high R&D expenditure ratio.

The main contributions of this paper are threefold. First, we speak to the literature regarding sustainable urbanization. Previous literature explores the nexus between urbanization and economic development, industrialization, and environmental performance (Henderson, 2002; Gollin et al., 2016; Liang et al., 2019; Liu et al., 2022). With increasing attention on sustainable development, recent literature focuses on the evaluation indicators and impacts of sustainable urbanization on population migration and pollution emissions (Guan et al., 2018; Li & Song, 2020; Zhao et al., 2022). Compared to previous literature, this study quantifies the effect of sustainable urbanization on economic growth quality and presents several plausible mechanisms. We show that sustainable urbanization promotes innovation, improves allocation efficiency, and has a screening effect on firm entry. This study enriches our knowledge on the impact of sustainable urbanization. Second, we advance the literature on the drivers of GTFP. Prior research focuses primarily on concrete factors, such as investment, technological innovation, and infrastructure improvement (Liu et al., 2021; Wu et al., 2020; Wang et al., 2024). This paper demonstrates that the active involvements and plans of governments can exert influence on GTFP. Third, through exploring how the promotion effect varies at the prefecture level, this study provides several important policy implications. We find that stringent environmental regulation, human capital accumulation and fiscal support are conducive to promoting GTFP. Hence, future sustainable urbanization should develop policies customized to local conditions and enhance supporting measures for sustainability.

The remainder proceeds as follows: Section 2 presents the background of the NUP and theoretical hypotheses. Section 3 explains data sources and econometric models. Section 4 discusses empirical results. Section 5 further explores the influencing mechanisms and the heterogeneity. The last section concludes.

2. Institutional background and theoretical hypotheses

2.1. The new-type urbanization plan in China

China, being the largest developing country, exhibits a traditional urbanization marked by "high input, high consumption, and high pollution". The negative externalities are more significant as China witnessed rapid urbanization in a short time (NBS, 2020; Wang et al., 2024).

Thus, to reduce the adverse effects of traditional urbanization, China has explored the path toward sustainable development and implemented the NUP. The policy follows the principle of "experiment first, expand later", which enables the building plan more tailored to local conditions. Specifically, 62 cities (towns) were selected as the first batch of new-type urbanization cities at the beginning of 2015. Then, at the end of the same year, the National Development and Reform Commisson (the NDRC) announced the second round of new-type urbanization cities. In December 2016, 111 cities (towns) were listed as the third batch of pilot cities.

The primary contents of the NUP include: (1) *Exploring the citizenship of the transferred rural population*. Due to some institutional barriers (e.g., the *Hukou* registration system), rural-to-urban and trans-regional migration is not free. Basic public services for the agricultural transfer population are not guaranteed. Hence, the NUP focuses on the civilization of the transferred rural population and relaxes some settlement policies. By providing education and skill training, the policy continuously improves the population's quality. (2) *Optimizing urban spatial layouts*. In fact, the urban spatial distribution contains two dimensions. Outside a city, the NUP emphasizes the coordinated development of urban clusters and guides the reallocation of industries from megacities to neighboring cities. And inside a city, the policy sets strict conditions for urban expansion and attempts to enhance the efficiency of space utilization. Green and low-carbon concepts should be integrated into the whole process of urban planning. (3) *Upgrading urban industrial structure and strengthening innovation capacity*. To this end, pilot cities are encouraged to foster strategic emerging industries and eliminate backward production regarding local conditions. Meanwhile, the policy requires pilot areas to agglomerate innovation elements (e.g., talents and funds) and create an innovation environment, which is beneficial for enhancing urban innovation. (4) *Enhancing governance capacity*. The transformation from rural China to urban China needs corresponding political changes to manage growing cities. Hence, pilot cities are encouraged to optimize administrative structures and divisions to reduce administrative costs. Besides, local governments need to strengthen information technology construction (e.g., big data and cloud computing) to improve governance efficiency.

To monitor the NUP implementation, the construction process is evaluated by four first-level indicators, including urbanization level, public service provision, infrastructure construction, and resource and environment. For each indicator, the central government sets specific targets to monitor and quantify the construction process. And local governments are required to submit new-type urbanization progress reports to the NDRC every year. And the central government implements some fiscal and industrial transfer methods, which enable pilot cities to promote sustainable urbanization construction better. Meanwhile, considering the process needs to be well financed, provincial governments and State Policy Banks provide multi-type financial instruments to support these pilot areas.

2.2. Theoretical hypotheses

As shown above, the NUP prioritizes harmonious development of society, population, industry, resources, and environment. By setting specific targets and providing policy support, pilot areas are motivated to transform their previous extensive development and cope with the social, economic, and environmental contradictions. In this way, sustainable urbanization can promote economic growth quality and thus has positive effects on green total factor productivity. Therefore, we put forward our first hypothesis.

H2: *New-type urbanization can promote green total factor productivity.*

From the construction plan, the NUP requires local governments to provide various economic incentives and aggregating innovation elements, which is conducive to improving city-level innovation capacity (Arrow, 1962; Li et al., 2020; Wang et al., 2019). Under the green and low-carbon orientation, pilot cities would improve their green innovation capacity through environmental regulation and the allocation of funds. The neoclassical economic and endogenous growth models indicate that technological progress is the linchpin to promoting productivity and economic growth (Romer, 1989, 1990; Solow, 1956). Meanwhile, the NUP points out to vigorously develop environmentally friendly and new-emerging industries. Such shifts toward these industries are beneficial for environmental quality and energy efficiency (Wang et al., 2024). Hence, industrial upgrading can help improve urban GTFP. Furthermore, the NUP emphasizes the importance of modern governance and administrative cost reduction, which can contribute to operation efficiency, thereby having a positive effect on GTFP (Lin & Zhu, 2021). Advanced technologies, including artificial intelligence, big data, and cloud computing, should be well exploited and developed throughout the construction of pilot cities. These technologies facilitate communication between firms and governments and accelerate information sharing, thereby promoting resource allocation efficiency (Cong et al., 2023). The influencing channels of the NUP on GTFP are shown in Figure 2. Given the analysis above, we propose our second hypothesis:

H3: *New-type urbanization can facilitate green innovation, upgrade industrial structure, and improve allocation efficiency, which are conducive to the promotion effect on GTFP.*

Finally, apart from average treatment effects, city governments would react differently to the new-type urbanization plan regarding their characteristics. For one thing, factor endowments in a city, such as fiscal abundance and human capital, are important determinants for the new-type urbanization construction. Sufficient fiscal support and well-educated citizens

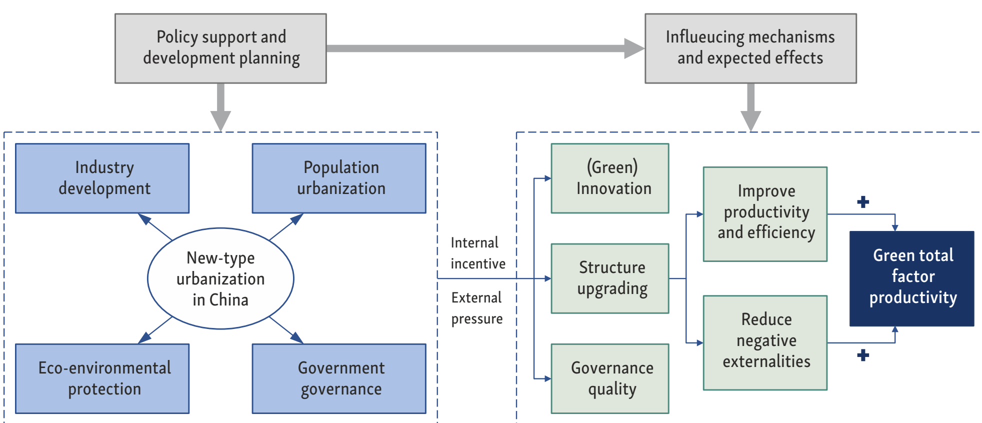


Figure 2. Influencing mechanisms of the NUP

can enable governments to finance corporate R&D activities, facilitate knowledge diffusion, and set higher standards for firm entry, which contribute to the quality of economic growth. The fiscal condition of local governments is an important influencing factor. For another, as the Porter hypothesis suggests, environmental regulation might impel firms to conduct more innovation activities, which will enhance their productivity and contribute to GTFP at the macro level (Porter & Linde, 1995). Therefore, the third hypothesis is illustrated as follows:

H4: *The more stringent environmental regulation and factor endowments (e.g., labor and fiscal support), the more pronounced the promotion of GTFP.*

3. Variables and empirical strategy

3.1. Data source

We choose the data sample from 2009 to 2018 to eliminate the shock of the financial crisis and the COVID-19 pandemic. The data we use for empirical analysis come from several sources. We obtain city-level characteristics from the Statistical Yearbook of Chinese Cities. Patent data are retrived from the China National Intellectual Property Administration. In particular, we focus on the application year of patents rather than the granted year as the former captures the real time of firms' innovation activities more accurately. Besides, we are also interested in innovation types because environmentally friendly innovation has more significant and direct effects on GTFP. Following the World Intellectual Property Organization (WIPO) guidelines, we collect green patents based on the Green List of International Patent Classification.[2] In addition, our entrepreneurship data is obtained from the State Administration for Industry and Commerce in China.

3.2. Variables

3.2.1. Green Total Factor Productivity (GTFP)

While China has made significant economic growth, it has also exacerbated serious environmental problems (Lin & Zhu, 2021). It is critical to detect undesirable byproducts of economic expansion, such as ecological externalities (Álvarez et al., 2020). Following Oh (2010) and Gao et al. (2022), we utilize the global Malmquist-Luenberger (GML) productivity index to calculate the GTFP, which can address potential infeasibility issues in measuring directional distance function (DDF). Specifically, we assume each city can produce M ($\mathbf{y} \in R_+^{M}$) desirable outputs and J undesirable outputs ($\mathbf{b} \in R_+^{J}$) by using N inputs ($\mathbf{x} \in R_+^{N}$). Let $\mathbf{g}$ = ($\mathbf{g_x}$, $\mathbf{g_y}$, $\mathbf{g_b}$) be a direction vector. The DDF is defined as $\vec{D}^t\left(\mathbf{x}^t, \mathbf{y}^t, \mathbf{b}^t; \mathbf{g}_x, \mathbf{g_y}, \mathbf{g_b}\right) = \max\left\{\beta \mid \left(\mathbf{y}^t + \beta\mathbf{g_y}, \mathbf{b}^t + \beta\mathbf{g_b}\right) \in \mathbf{P}\left(\mathbf{x}^t + \beta\mathbf{g}_x\right)\right\}$. Based on the DDF, we can construct the GML productivity index as the following equation.

$$GML_t^{t+1}\left(\mathbf{x}^t, \mathbf{y}^t, \mathbf{b}^t, \mathbf{x}^{t+1}, \mathbf{y}^{t+1}, \mathbf{b}^{t+1}\right) = \frac{1 + \vec{D}^G\left(\mathbf{x}^t, \mathbf{y}^t, \mathbf{b}^t\right)}{1 + \vec{D}^G\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}, \mathbf{b}^{t+1}\right)}. \quad (1)$$

[2] Information can be found in: https://www.wipo.int/classifications/en

To compute GTFP, following Álvarez et al. (2020), we use the data envelopment analysis toolbox in MATLAB. The GML calculation requires input, desirable and undesirable outputs. First, according to the Solow model (Solow, 1956), labor and capital are two crucial variables for economic growth. Thus, input variables include labor and capital. Since capital data disclosed in the statistical yearbook is a flow variable, we transform the flow variable into capital stock with the equation $K_{t+1}=(1-\delta)K_t + I_{t+1}$ (Chen & Tang, 2018). Meanwhile, electricity is increasingly important in supporting China's industrialization and modernization. We also treat electricity use as an input variable. Second, our desirable output is regional real GDP, as has been done in prior literature (Gao et al., 2022). This is primarily because the most important thing for all levels of government is to promote economic growth. Third, among undesirable outputs, pollution emissions represent the most adverse consequence of economic advancement. This research employs industrial SO_2 and wastewater discharges to signify these unwanted byproducts. The reasons are twofold. For one thing, industrial SO_2 and wastewater emissions are typical pollution emissions arising from economic activities. The harmfulness and pollution disposal difficulties of these two types are large as they can easily spread through wind and rivers (Chen et al., 2018; Kong & Qin, 2021). Hence, the central government in China has formulated some measures to reduce SO_2 and wastewater emissions (e.g., two-control zones policy). For another, due to their negative externalities, the information disclosure requirements of SO_2 and wastewater emissions are also strict. Hence, we can obtain high-quality pollution emission data for our analysis.

3.2.2. New-type urbanization plan (NUP)

As shown in the background, the new-type urbanization pilot policy is the core independent variable of this study. We generate the NUP_{it} variable to conduct the DID estimation according to the policy's commencement date in each prefecture-level city. NUP_{it} is a dummy variable, where i indexes i-th city and t indexes t-th year. NUP_{it} takes the value one when and after i-th city is selected as the pilot city for new-type urbanization. Otherwise, NUP_{it} takes the value zero.

3.2.3. Covariates

Other factors, such as economic development levels and industrial structure, might affect GTFP. Hence, following Xu and Yang (2022) and Wang et al. (2024), we control for potential city-level time-variant disturbances, including economic development (*LPGDP*), industrial structure (*Stru*), population size (*LPOP*), urbanization rate (*Urban*), population density (*Ldensity*), and foreign direct investment (*Open*). To avoid the influence of outliers, all continuous variables are winsorized at 1% on both tails of their distributions. Nominal values are deflated to the price of the base year. Detailed definitions and summary statistics of these variables are shown in Table 1.

Table 1. Descriptive statistics

Variables	Definitions	Obs	Mean	Sd
GTFP	Green total factor productivity, illustrated in section 3.2.1	2,567	0.939	0.271
NUP	A dummy variable for new-type urbanization, illustrated in section 3.2.2	2,679	0.097	0.296
LPGDP	The logarithm of regional gross domestic product per capita	2,679	1.097	0.578
Struc	The ratio of secondary industry to ternary industry	2,679	1.354	0.544
LPOP	The logarithm of registered population	2,679	5.903	0.615
Urban	The ratio of non-fram payros to total employment	2,679	0.979	0.042
Ldensity Open	The logarithm of the ratio of local population to land area	2,679	5.768	0.848
Open	The ratio of foreign investments to gross regional product	2,679	0.014	0.014

3.3. Empirical strategy

Our identification strategy is a staggered difference-in-differences specification. We estimate the following form to quantify the impact of the NUP on GTFP:

$$GTFP_{it} = \beta_0 + \beta_1 \cdot NUP_{it} + \gamma \cdot \mathbf{X}_{it} + \mu_i + v_t + \varepsilon_{it}, \quad (2)$$

where i stands for i-th city, and t denotes t-th year. $\mathbf{X}_{it}$ means a vector of time-varying city-level disturbances and γ shows corresponding coefficients. μ_i and v_t denote city and time fixed effects, respectively. ε_{it} represents the error term. Considering potential heteroscedasticity, this paper clusters standard errors at the city level. We are interested in the estimated sign and magnitude of β_1. A significantly positive sign of β_1 indicates that the *NUP* in China contributes to improving GTFP. In contrast, a negative sign means the *NUP* impedes GTFP.

4. Main results

4.1. Baseline estimation

Using the staggered DID model shown in equation (2), we estimate the impact of the NUP on GTFP. Table 2 reports the calculated results. The coefficient in Column (1), without control variables, is 0.025, implying that the NUP can promote urban GTFP preliminarily. After sequentially introducing control variables, we find that the estimated coefficients of β_1 vary slightly, and the positive effect on GTFP remains unchanged. Column (4) presents the baseline result controlling for covariates and two-way fixed effects. According to the magnitude of β_1, the NUP increases GTFP by three percentage points on average, measured by the absolute value. Given the average size of GTFP in our sample, the result indicates that the NUP promotes GTFP by 3.2% (=0.030/0.939), which is statistically and economically significant. Therefore, the new-type urbanization in China contributes to promoting GTFP, supporting our first hypothesis.

Table 2. The impact of sustainable urbanization on GTFP

	Dependent variable: GTFP			
	(1)	(2)	(3)	(4)
NUP	0.025** (0.012)	0.028** (0.012)	0.030** (0.012)	0.030** (0.012)
LPGDP		–0.037 (0.030)	–0.032 (0.030)	–0.026 (0.032)
Struc		–0.024 (0.019)	–0.022 (0.019)	–0.024 (0.019)
LPOP			–0.079 (0.056)	–0.081 (0.057)
Urban			–0.830** (0.359)	–0.831** (0.360)
Ldensity				0.003 (0.031)
Open				–0.482 (0.469)
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Obs	2,567	2,567	2,567	2,567
Adjusted R-squared	0.651	0.652	0.653	0.653

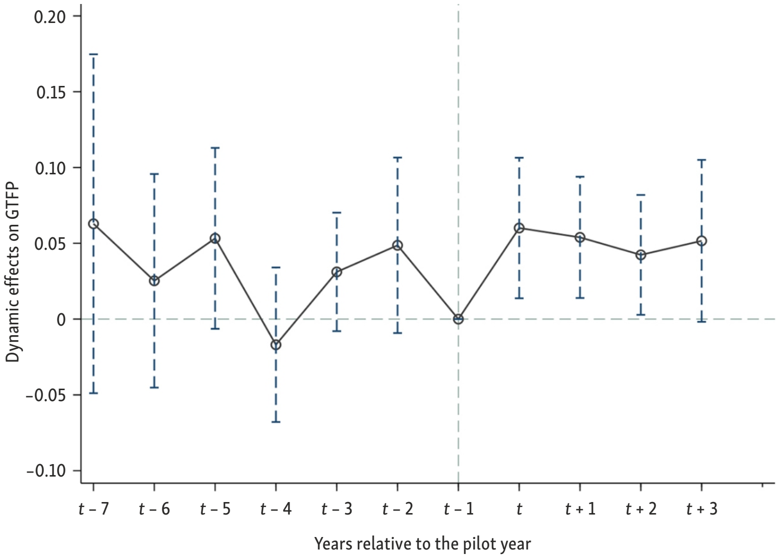
Note: Robust standard errors in parentheses are clustered at the city level. Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The same is below.

4.2. Parallel trend test

One major concern to our estimation is that the difference in GTFP of the two groups might be influenced by some unobserved city-level characteristics rather than triggered by the NUP. The validity of the DID specification depends on the prerequisite that pilot and non-pilot cities should have similar pre-trends regarding GTFP. To address this concern, following Serfling (2016), this study employs an event study approach to verify the parallel trend assumption, which is given as:

$$GTFP_{it} = \beta_0 + \sum_{k=2}^{8} \beta_{-k} Before_{it}^{-k} + \beta_{+0} \times Current_{it} + \sum_{b=1}^{3} \beta_{+b} After_{it}^{+b} + \mu_i + v_t + \varepsilon_{it}. \quad (3)$$

$Before_{it}^{-k}$ (k = 2, ..., 8) is a time dummy, taking 1 in k years before i-th region selected as the new-type urbanization city, and otherwise zero. Similarly, $After_{it}^{+b}$ (b = 1, 2, 3) takes value 1 in b years after i-th region selected as the new-type urbanization city and otherwise zero. $Current_{it}$ represents the pilot year. The omitted time variable is one year before the pilot year. If the results support the parallel trend, estimates of β_{-k} are supposed to be around zero (Xu & Yang, 2022). And β_{+b} (b = 0, 1, 2, 3) measures the dynamic effects of the NUP. Figure 3 plots the point estimates and their confidence intervals before and after the policy. We find that all the coefficients β_{-k} (k = 2, ..., 8) are not significantly different from zero, whereas coefficients β_{+b} (b = 0, 1, 2, 3) are significantly positive. The results show that there is no pre-existing



Notes: The hollow dots denote estimated coefficients and dashed lines show their corresponding 95% confidence intervals.

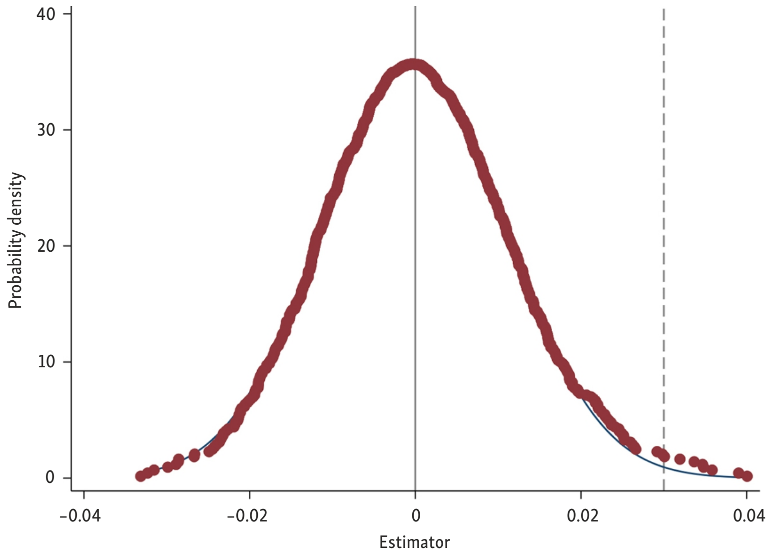
Figure 3. Event study estimates

trend in GTFP between control and treatment cities. Nevertheless, after the implementation of the NUP, these treated cities have a relatively high GTFP, which increases the confidence in the validity of the staggered DID estimation.

4.3. Robustness tests

4.3.1. Placebo test

Although the overall effect shows that the NUP improves GTFP, this could occasionally be influenced by other undisclosed determinants. Therefore, we employ the placebo test to verify that the NUP promotes GTFP instead of being an occasional finding. Concretely, this study randomly selects pilot years and pilot cities to work as "fictitious treatment" groups. Regarding the staggered DID model, we randomly choose three years and 77 cities (the number of pilot cities in our sample) to create the fictitious treatments and then repeat the baseline regression 1000 times. Since the generated treatment groups are fictitious, the estimated coefficients of the DID variable might be around 0. Figure 4 plots the estimated coefficients. We find that the coefficients of falsifying treatments are mostly around 0, indicating no significant promotion effect on GTFP using the fictitious treatment groups. And the real coefficient of the *NUP* variable in the baseline result is 0.030, far beyond the 5% critical value of the estimated fictitious coefficients. Thus, the promotion effect of the NUP on GTFP is not an occasional finding.



Note: The dots are the estimated coefficients of the fictitious treatments. The gray dash line is the real point estimate with a value of 0.030.

Figure 4. Placebo test

4.3.2. PSM-DID estimation

Another concern is that the pilot cities for new-type urbanization might not be chosen randomly. The NDRC may prioritize the new-type urbanization pilots in regions with highly-developed economic conditions and favorable natural circumstances, which will cause some bias problems. To account for potential selection biases, we employ the PSM-DID method to ensure our baseline results are robust (Zhang et al., 2017). Specifically, we pool the observations and calculate their propensity scores using prefecture-level characteristics. Then we select some control groups with high propensity scores compared to the treatment groups. Using the sample comprised of the treatment groups and selected control groups, we report the PSM-DID estimation in Column (1) in Panel A of Table 3. The result shows that the NUP increases GTFP by 2.9 percentage points, which changes slightly compared to our baseline result. Besides we also match pilot cities with control cities year by year according to their prior information. Column (2) of Panel B indicates that the positive effect of the NUP on GTFP still holds.

4.3.3. Other robustness tests

To validate our baseline estimation, we also conduct other robustness tests. First, considering that provincial capital cities might be politically favored and resource-supported in China, we exclude these provincial capital samples and re-estimate the baseline regression. Column (1) in Panel B of Table 3 shows the estimated coefficient is still significantly positive. Second, the policy covers some county-level regions within a city. The impact of sustainable urbanization on GTFP might be weakened. Hence, we eliminate those cities that only have some counties as the pilots and find that the positive effect on GTFP changes slightly, as shown in Column (2). In addition, we only keep the first round of new-type urbanization cities. The estimated result, as shown in Column (3), still remains statistically positive. Therefore, sustainable urbanization in China can promote urban GTFP, which is robust to a vector of vigorous checks.

Table 3. PSM-DID and other robustness tests

	Dependent variable: GTFP		
	(1)	(2)	
Panel A. Propensity score matching			
NUP	0.029** (0.013)	0.029** (0.015)	
Obs	1654	1208	
Adjusted R^2	0.674	693	
	Dependent variable: GTFP		
	(1)	(2)	(3)
Panel B. Other robustness tests			
NUP	0.029** (0.013)	0.028** (0.013)	0.037*** (0.014)
Covariates	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Obs	2,331	2,002	2,389
Adjusted R^2	0.651	0.663	0.656

Note: **Panel A** reports PSM-DID estimation. **Panel B** reports other robustness tests.

5. Further analyses

5.1. Potential mechanisms

Thus far, baseline results show strong evidence that the NUP in China can significantly promote GTFP. This section further explores the mechanisms through which the NUP affects city-level GTFP. In Section 2.2, we elaborate on the potential mechanism of the NUP on GTFP from three perspectives: promoting innovation, especially green innovation, upgrading industrial structure, and improving allocation efficiency.

5.1.1. Promoting innovation

In response to the policy, local governments are highly likely to provide R&D subsidies to support new-type urbanization construction. Referring to Xia and Xu (2020), we first use the logarithm of urban R&D expenditures and the ratio of R&D expenditure to total fiscal expenditure to examine this mechanism. As shown in Columns (1)–(2) of Table 4, we find that the NUP directly boosts local R&D investment, which serves as a key factor in improving green total factor productivity. Nevertheless, R&D investment is an input indicator and does not always bring about technological advancements due to risky and uncertain innovation activities. Following the innovation literature, we use the number of patents to denote the innovation capacity of a city. According to patents' originality, we use the logarithm of invention patents counts (ln*Patents*) and green invention patents counts (ln*Green_patents*) applied by and eventually granted to a city as the proxy of a city's innovation capacity. Column (3) of Table 4 indicates that the NUP also promotes urban innovation, as measured by invention patent counts. The magnitude is statistically and economically significant as the NUP improves successful invention patent applications by 27.6%. Furthermore, Column (4) shows that the NUP also significantly facilitates green innovation. On average, the NUP increases green invention patents of the pilot cities by 13.9%. As a result, the NUP contributes to facilitating green transformation and reducing environmental externalities, thereby improving GTFP.

Table 4. The impact of the NUP on innovation activities

Dependent variable	ln*R&D*	*R&D* ratio	ln*Patents*	ln*Green_patents*
	(1)	(2)	(3)	(4)
NUP	0.103* (0.060)	0.050*** (0.018)	0.276*** (0.066)	0.139** (0.070)
Controls	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Obs	2,679	2,679	2,667	2,665
Adjusted R^2	0.917	0.751	0.952	0.931

5.1.2. Upgrading industrial structure

Industrial upgrading consists of two aspects: industrial advancement and industrial rationalization (Wang et al., 2024; Zhou et al., 2020). Following prior literature, we use the ratio of secondary industry to tertiary industry as a measure of industrial advancement. As for industrial rationalization, it compares the relative share of industrial employment and industrial output. Referring to Wang et al. (2024), we employ the following formula to calculate industrial rationalization:

$$IR = 1 - \frac{1}{3}\sum_{i=1}^{3}\left|\frac{Y_{it}}{Y_t} - \frac{L_{it}}{L_t}\right|,\ i = 1, 2, 3, \tag{4}$$

where Y_{it} and L_{it} depict the final output and employment of *the i-th industry in the t-th year*, respectively. Y_t and L_t represent regional gross domestic product and employment. If sustainable urbanization promotes economic quality through the industrial upgrading channel, we can expect a positive effect on industrial advancement and rationalization. However, as shown in Columns (1)–(2) of Table 5, the coefficients are not significant, even at the 10% significance level. We cannot find supporting evidence that the NUP contributes to upgrading industrial structure in a city.[3] One highly probable reason is that the industrial structure measure is a stock indicator comprised of incumbents and cannot be adjusted in the short term. And the

[3] To avoid the perfect collinearity, the covariates do not include the variable *Struc* while other settings are the same to the baseline model.

new-type urbanization plan shows very little effect on upgrading industrial structure in our research period. Then, we turn our focus to new entrants. As the public interest theory suggests, governments would consider the environmental consequences of new entrants and reduce the entry of polluting industries (Djankov et al., 2002). Through screening, local governments can keep out those projects or entrepreneurs that are not attractive. If that is the case, we would find a significant increase in the entry of non-polluting firms relative to polluting firms. We extract the industry attributes of new establishment firms from registration data and divide them into polluting and non-polluting firms.[4] The estimates are presented in Columns (3)–(4) of Table 5. We find that new entrants that are pollution-intensive in pilot cities drop by 8.3% relative to non-pilot cities, which is statistically significant. On the contrary, the entry of non-polluting firms increases by 5.9%, implying that the NUP has a screening effect on new firm entry and drives the industrial structure towards a clean path. Local governments might improve their green total factor productivity by restricting the development of polluting industries and encouraging non-polluting industries. Overall, our empirical evidence does not support the industrial upgrading mechanism, as measured by industrial advancement and rationalization. But we can find positive signs of industrial adjustment.

Table 5. Upgrading industrial structure

Dependent variable	Industrial advancement	Industrial rationalization	Polluting firms (log)	Non-polluting firms (log)
	(1)	(2)	(3)	(4)
NUP	0.005 (0.032)	–0.008 (0.006)	–0.083** (0.038)	0.059* (0.035)
Controls	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Obs	2,679	2,679	2,665	2,673
Adjusted R^2	0.888	0.801	0.942	0.958

5.1.3. Improving allocation efficiency

The intelligent and intensive development of cities is an extremely important direction for building new urbanized cities. Local governments are required to coordinate the use of material, information, and intellectual resources to promote the efficiency of production activities and social governance. In this way, the NUP might optimize resource allocation and eventually improve allocation efficiency. As the GML index can be decomposed into technological change and efficiency change, we employ the efficiency change to represent allocation efficiency. Table 6 presents the estimated results. A positive coefficient indicates that the NUP also significantly boosts the allocation efficiency, with or without control variables. Hence, our mechanism analyses generally support Hypothesis 2. Although the upgrading effect of sustainable urbanization on industrial structure is not significant, we find positive clues on the green transformation of industrial structure from firm registration data.

[4] The official classification is the Management Directory of Listed Companies' Environmental Verification Industry Classification. Detailed information can be found at: https://www.mee.gov.cn/gkml/hbb/bgth/200910/t20091022_174891.htm

Table 6. Promoting allocation efficiency

Dependent variable	Efficiency change	Efficiency change
	(1)	(2)
NUP	0.025** (0.010)	0.028*** (0.010)
Controls	No	Yes
City fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Obs	2616	2616
Adjusted R^2	0.119	0.121

5.2. Heterogeneous effects of sustainable urbanization on GTFP

Our baseline shows the average treatment effects of sustainable urbanization on GTFP. Nevertheless, this effect might exhibit heterogeneity regarding city characteristics. In this part, we further examine whether the main results vary across cities with different environmental regulation stringency and factor endowments.

5.2.1. Environmental regulation

Stringent environmental regulation would induce more innovation activities and reduce pollution emissions (Porter & Linde, 1995; Gao et al., 2024), which benefits green total factor productivity. Hence, we expect that cities with stringent regulation will have more pronounced promotion effects on GTFP. Following existing literature, we mainly employ two environmental regulation measures to explore the NUP's heterogeneous effects. First, considering that regional pollution levels negatively correlate with regulation intensity, we use the indicator measured by Ye et al. (2018) to represent regulation intensity. We construct two dummy variables. *High_Reg*1 takes value one when a city's pollution emissions are less than the median in a year. And *Low_Reg*1 equals one when the number is larger than the median. Second, environmental concerns from local governments can also reflect the stringency to mitigate pollution. Following Chen et al. (2018), we use the ratio of environment-related words to the number of all words contained in city-level governments' annual work reports. And we define two dummy variables – *High_Reg*2 and *Low_Reg*2 – to classify regions into high and low regulation intensity groups according to the median of the ratio in a respective year. *High_Reg*2 takes value one when a city's ratio of environmental words is larger than the median; otherwise zero. And *Low_Reg*2 takes the opposite.

Then we add these pairwise interaction terms (e.g., *NUP*×*High_Reg*1 and *NUP*×*Low_Reg1*) into the baseline regression. Following Xu and Yang (2022), we drop the original NUP term to avoid perfect collinearity. The estimated results are shown in Panel A of Table 7. We find that cities with strong environmental regulation intensity tend to have a higher GTFP. And different measures of environmental regulation intensity do not influence our results. The estimated coefficients of high-regulation interaction terms (i.e., *NUP*×*High_Reg*1, and *NUP*×*High_Reg*2) are significantly positive at the 5% significance level, while those of low-regulation interaction terms are much lower and insignificant. Thus, these results align with the hypothesis that environmental regulation contributes to improving GTFP.

Table 7. Heterogeneous responses to the NUP

	Dependent variable: GTFP	
	(1)	(2)
Panel A: The role of environmental regulation		
*NUP×High_Reg*1	0.031** (0.014)	
*NUP×Low_Reg*1	0.025 (0.018)	
*NUP×High_Reg*2		0.037** (0.015)
*NUP×Low_Reg*2		0.022 (0.014)
Obs	2,567	2,567
Adjusted R^2	0.653	0.653

	Dependent variable: GTFP		
	(1)	(2)	(3)
Panel B: The role of human capital, fiscal support, and R&D expenditure			
NUP×High_Human	0.048*** (0.013)		
NUP×Low_Human	–0.006 (0.020)		
NUP×High_Fiscal		0.044*** (0.013)	
NUP×Low_Fiscal		0.009 (0.019)	
NUP×High_R&D			0.035*** (0.013)
NUP×Low_R&D			0.013 (0.022)
Controls	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Obs	2,567	2,567	2,567
Adjusted R^2	0.653	0.653	0.653

Note: Panel A reports the impact of environmental regulation. Panel B says the impact of human capital, fiscal support and R&D expenditure on GTFP.

5.2.2. Factor endowments

Implementing the NUP requires both fiscal support and the accumulation of human capital. Hence, the promotion effect on GTFP might vary across different levels of factor endowments. To shed light on this, we construct two binary variables – *High_Human* and *Low_Human*, to classify sampled cities into high- and low-human capital cities according to the median number of college students. The more college students, the larger the human capital accumulation and the stronger the capacity to implement sustainable urbanization. As a result, the impact of sustainable urbanization on GTFP can be strengthened. Column (1) in Panel B of Table 7 shows that the point estimate of *NUP×High_Human* is positive at the 1% significance level, while the coefficient of *NUP×Low_Human* becomes negative but not significant. Hence, the promotion effect of the NUP tends to be larger in cities with more human capital.

Besides, we define two indicators measuring city-level fiscal abundance and its orientation towards R&D activities. The first measure is the fiscal expenditure per capita. The second measure calculates the ratio of the expenditure of science and technology to the total fiscal expenditure of a city. Similar to the above processes, we define four dummy variables, *High_Fiscal* vs *Low_Fiscal* and *High_R&D* vs *Low_R&D*, to classify the sampled cities. As shown in Columns (2)–(3) in Panel B, pilot cities with greater fiscal abundance and R&D ratio increase more in green total factor productivity following the NUP. Comparatively, the promotion effect on GTFP is not statistically and economically significant in low-fiscal and low-R&D groups. These results suggest that local fiscal support (like R&D subsidies) is essential for implementing such sustainable urbanization strategy, which contributes to corporate R&D activities and improves GTFP (Grant et al., 2019; Qi et al., 2020). These results support our third hypothesis that more stringent environmental regulation and factor endowments (e.g., labor and fiscal support) can contribute to the promotion of GTFP.

6. Conclusions and policy implications

Urbanization implies better infrastructure, more job opportunities, as well as huge resource consumption. Enhancing urbanization quality and fostering sustainable development stands as a key concern for policymakers worldwide. Based on the specific practices of the largest developing country, i.e., China, this paper estimates the impact of a sustainable urbanization policy on the quality of economic growth in China. We find that the NUP can significantly promote GTFP, increasing GTFP by 3.2% on average. The promotion effect of the NUP on GTFP is robust when using various alternative specifications. Hence, the new-type urbanization plan in China is an outstanding attempt to pursue sustainable urbanization and improve the quality of economic growth.

We illustrate several plausible channels driving the promotion effect, including facilitating green innovation, upgrading industrial structure, and improving allocation efficiency. Comparatively, industrial upgrading, as measured by industrial advancement and rationalization, cannot be verified by our empirical evidence. Instead, the NUP might impel local governments to screen the entry of new firms and retain these non-polluting firms. In this sense, local industrial structures are upgraded at a gradual pace. Besides, we find that the intensity of environmental regulation is important for achieving better promotion effects on GTFP. And the increase in GTFP is more pronounced in regions with strong regulation intensity, regardless of different environmental regulation measures. In addition, we find that government interventions are also essential for promoting GTFP. The promotion effects on GTFP are more salient in regions with stringent environmental regulation, adequate human capital, sufficient fiscal support, and a high R&D expenditure ratio.

As developing nations strive for sustainable urbanization with large populations, this paper has several important policy implications. First, such a sustainable urbanization policy is essential to guide local governments in transforming their previous excessive development mode. In the context of carbon neutrality, promoting urban sustainable development is important for addressing climate change. This paper shows that through external pressure and internal incentives, the government-led practice in China can promote innovation, improve allocation efficiency, and have higher standards on firm entry, which are conducive to economic growth quality. Hence, based on country-specific conditions, other developing countries can formulate their own urbanization policies to guide sustainable urban development. Second, stringent environmental regulation is needed to guarantee the policy effect. This is primarily because that stringent environmental regulation can ensure local compliance with policies and guidelines. Some policy targets (e.g., environmental protection and industrial structure) can be easily achieved, which is conducive to sustainable development. Third, governments should make some tailored policies to accumulate talent and funds. Our paper shows that the availability of resources in a city affects the effectiveness of the NUP. Cities with high human capital and fiscal (R&D) abundance exhibit a significant promotion effect on GTFP.

We shed light on the role of sustainable urbanization. Nevertheless, this study has two limitations regarding data availability and research perspective, which can be extended in future research. First, we only focus on one country and show that China's sustainable urbanization can promote economic growth, as measured by GTFP. Although the urbanization process is somewhat similar, the impact might be heterogeneous as countries have different institutional arrangements, legal systems, and ethnic compositions. Hence, future research can compare the implementation of country-specific sustainable urbanization policies and conduct some cross-country analyses. Second, achieving sustainable urbanization is not built in a day, which might need policy synergies. Thus, more work can be done to study the role of policy synergies on economic growth quality.

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