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Does State-level Upgrade of High-tech Zones Promote Urban Innovation Efficiency: Evidence from China

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Abstract: Among China's existing state-level High-tech Industry Development Zones (HIDZ), the number of upgraded ones account for more than 65%, which are supposed to fulfill the important mission of leading innovation. However, while the upgraded state-level HIDZ enjoy more opportunities than before, they also face major challenges such as the significant inter-generational differences between them and the born state-level HIDZ. Based on the panel data of Chinese (prefecture-level) cities from 2007 to 2015, the paper empirically examines the impact of the state-level upgrade of HIDZ on urban innovation efficiency by using a difference-in-differences propensity score matching approach (PSM-DID). The results show that the upgraded state-level HIDZ has significantly improved urban innovation efficiency, and this positive effect has gradually increased with the implementation of the upgrade policy. The further heterogeneity analysis shows that the higher the scientific research level of higher education institutions in the cities, the greater the promotion effect of the state-level upgrade. The paper evaluates the policy effect of the upgraded state-level HIDZ from their stated mission, which is a powerful complement to the existing research and provides more effective guidance for policy-makers.

Keywords: China; upgraded state-level HIDZ; urban innovation efficiency; PSM-DID

1. Introduction

China's State-level High-tech Industry Development Zones (HIDZ), the backbone of the country's high-tech industries, are a critical driver of China's innovation and economic growth. According to the statistics of China's Torch High Technology Industry Development Center, by the end of 2018 there were 168 state-level HIDZ (excluding Suzhou Industrial Park), of which 53 were originally established ones, while 115 were upgraded from province-level development zones. Accounting for more than 65% of the total number, the upgraded state-level HIDZ are supposed to shoulder the important mission of leading innovation. However, the evaluation results announced by the center in 2018 show that almost all of the upgraded state-level HIDZ have lower performance than the born ones. The possible reason for this is that the approval time of upgraded state-level HIDZ is later (concentrated during 2007–2018), most of which are located in the second- or third-tier cities, or even county-level regions. Thus, they are facing major challenges, such as insufficient endogenous innovation capacity, lower value chain position, factor scarcity, and single aggregation means, etc. [1].

However, the opportunities from state-level upgrade for HIDZ and their cities are also significant. The most direct ones are the greatly improved policy advantages. The upgraded state-level HIDZ will enjoy more favorable state-level policies of administration, land resources, exports, credit, and tax, etc. Meanwhile, the state-level upgrade of province-level HIDZ is also a major strategic arrangement to make China a country of innovators. The state-level upgrade is necessary for further optimizing the strategic spatial structure of the state-level HIDZ and promoting the more balanced regional development. It is exactly due to the coexistence of challenges and opportunities, as well as the mission of leading innovation and balanced development, that the policy effect of the state-level upgrade of HIDZ has become a major practical issue of concern for both academics and policy-makers [2].

As a place-based industrial policy, there are a lot of existing studies on development zones including state-level HIDZ and their impact on regional or corporate economic performance. However, the following problems still exist and deserve further exploration. First, most of the existing literatures have not distinguished between the originally established development zones and the upgraded ones, but there are significant differences between them in terms of time, space, market competitiveness, and institutional environment [3]. Based on the data from Chinese prefecture-level cities, the existing literatures studied the impact of development zones establishment on local foreign investment (Wang, 2013) [4], local economic development (Alder, et al., 2016) [5], enterprise exports (Schminke, et al., 2013) [6], etc. However, the above literatures regarded all of the development zones as the same, while ignoring the important distinction resulting from the different development ways.

Second, although there are a few scholars who focus on the upgraded development zones, they either do not evaluate the policy effect or pay little attention to evaluating the policy effect from the specific types of the zones' stated mission. For instance, Xue and Zhao (2014) analyzed the main characteristics and innovative development paths of 32 upgraded state-level HIDZ based on the theories of industrial ecology [1]. Zhen and Li (2018) elaborated the inter-generational differences between the upgraded state-level HIDZ and the originally established ones based on self-organization theory [3]. They both focused on the features and development paths of the upgraded state-level HIDZ, but did not evaluate their policy effect. Based on the data of Chinese industrial enterprises, Huang and Wang (2017) examined the policy effect of the upgraded development zones on enterprise exports [7]. However, they ignored that the development zones differ in their stated mission [8]. Different missions will inevitably bring about different oriented policies. Specifically, the state-level HIDZ are the backbone for China to implement the innovation-driven development strategy by fostering high-tech industries [6]; the state-level Economic and Technological Development Zones (ETDZ) are critical for attracting foreign investment and promoting industrial clusters, while most of the province-level zones mainly focus on building industrial agglomeration areas [5]. Therefore, it is more instructive for policy-makers to evaluate the policy effect of upgraded zones from their own stated mission.

In order to fill the above research gaps, this paper focuses on the upgraded state-level HIDZ and intends to evaluate the policy effects from their stated mission. The upgraded state-level HIDZ, which have absolute advantages in quantity, are equally important with the originally established ones, but have not received enough scholarly attention. In the background of the innovation-driven development of China, being strategic highlands for leading innovation and important engines to promote economic transformation, has become the core function of the state-level HIDZ [9]. Urban innovation efficiency can well measure the fulfillment of this stated function. Therefore, using urban innovation efficiency to evaluate the policy effect of the state-level upgrade can provide more useful information for policy-makers. Meanwhile, existing literatures on the factors influencing urban innovation efficiency have mainly focused on the R&D activities of innovation entities (e.g., enterprises, governments, universities and other research institutions), the communication among them, and innovation environment (e.g., economy, infrastructure and culture) [10]. Although factors such as government R&D investment and innovation environment may be related with the mechanism of state-level HIDZ affecting urban innovation efficiency, there is still a gap of direct examination on how state-level HIDZ, especially the upgraded ones, affect urban innovation efficiency. Thus, the paper takes China's large-scale state-level upgrade of HIDZ in 2010 as a quasi-natural experiment and uses difference-in-differences propensity score matching approach (hereinafter referred to as "PSM-DID") [11] to evaluate the impact of the upgraded state-level HIDZ on urban innovation efficiency.

An additional heterogeneity analysis is conducted based on the scientific research level of higher education institutions in the cities.

This study contributes the following to the literature: First, due to the inter-generational differences between the upgraded state-level HIDZ and the originally established ones, this paper takes the former as the research objective, which fills the gap of the existing studies focusing on the total or the originally established state-level HIDZ in China. Second, the paper evaluates the policy effect of the upgraded state-level HIDZ by urban innovation efficiency, which is closely related with their stated mission, and further identifies the boundary conditions for guaranteeing a positive policy effect. It provides more effective guiding for the upgraded state-level HIDZ to better seize opportunities and cope with challenges, and then successfully fulfill the mission given by the country. Third, the paper uses the PSM-DID method, which to some extent overcomes the endogenous and sample selection bias problems, and eliminates the interference from other factors, so as to accurately identify the net effect of the state-level upgrade policy.

2. Theory and Hypotheses

2.1. Upgraded State-level HIDZ and Urban Innovation Efficiency

Conclusions of existing research on the policy effect of state-level HIDZ and its mechanism can be summarized as three aspects: "policy rent" effect, benefiting from the series of preferential policies (Moberg, 2015) [12], "agglomeration effect", driving industry and talent gathering (Lin, et al., 2018) [13], "selection effect", promoting survival of the fittest, and "cage change for birds" (Wang and Zhang, 2016) [14]. Compared to the born state-level HIDZ, the financing environment and infrastructure condition of the upgraded ones are relatively poor. Thus, according to the marginal rule of fiscal incentives, the upgraded state-level HIDZ will be more motivated to invest in innovative activities brought by better preferential policies (financial subsidies, tax incentives, etc.), and the degree of benefit from the agglomeration economy may also be higher (Lu, et al., 2015) [15]. Specifically, the state-level upgrade of HIDZ can influence the urban innovation efficiency in at least two ways:

(1) The state-level upgrade of HIDZ is conducive to the agglomeration of urban innovation resources, which are both from public sectors and private ones. First, the "signal effect" brought about by the state-level upgrade will directly increase the land value and then the government's fiscal revenue. The local government is therefore better able to attract high quality innovation resources through more competitive innovation incentives. The increase in government fiscal revenue has also provided guarantees for urban infrastructure and information construction. Therefore, the cost of transportation and information exchange among enterprises can be effectively reduced, which will improve their transaction activities and accelerate the flow of innovative elements such as knowledge in the cities. In turn, it helps to build a good, open innovation environment in which synergies will be created, and then promote urban innovation efficiency (Boschma and Iammarino, 2015) [16].

Second, the state-level upgrade also plays a signal role in the credit market. The state-level identity endorses development potential and commercial credit for the enterprises in the zone, which will effectively alleviate the financing constraints of their R&D and other innovation activities (Kleer, 2010; Doh and Kim, 2014) [17,18]. The continuous supply of bank credit is also critical for enterprise innovation efficiency (Laeven and Valencia, 2012) [19]. This will in turn positively impact the overall innovation efficiency of the city.

Third, with more preferential policies, the upgraded state-level HIDZ will attract more qualified high-quality enterprises to enter, thus accelerating industrial agglomeration in the zones (Combes, et al., 2010) [20]. Industrial agglomeration will improve the HIDZ innovation efficiency through sharing intermediate input, labor market reservoirs, and knowledge spillover, further promoting innovation efficiency in neighboring regions through spatial spillover effect (Wang and Zhang, 2016) [14], thus contributing to urban innovation efficiency.

(1) The upgraded state-level HIDZ will promote urban innovation efficiency through optimizing the allocation of urban innovation resources. First, compared with province-level HIDZ, financial subsidies and tax incentives will be preferentially allocated to state-level HIDZ. Greater innovation incentives will stimulate urban innovation by reducing enterprises innovation costs, risks, and increasing their earnings (González & Pazó, 2008; Guo, et al., 2016) [21,22]. Second, government administrative efficiency has also been improved. The upgraded state-level HIDZ which are led by the central government have fairer and more transparent process for institutional formulation and implementation than the province-level ones. And the management committee of state-level HIDZ generally enjoys the local and municipal economic management authority, which greatly shortens the administrative approval processes and reduces the transaction costs of innovation. In addition, the improvement of government service quality has also provided a good institutional environment for enterprise innovation, which is helpful for HIDZ innovation efficiency. Finally, the upgraded state-level HIDZ will transfer the high-quality innovation resources from low-efficiency enterprises to high-efficiency ones through the "selection effect", thereby improving urban innovation efficiency.

However, the policy effect of the upgraded state-level HIDZ on urban innovation efficiency is not a one-step process. Although the preferential policies can be adjusted immediately, the infrastructure investment and construction, the industrial agglomeration, the adjustment and improvement of management systems, and the effects of spatial spillovers are all needed to be gradually revealed and strengthened over the time. Therefore, our paper proposes the following:

Hypothesis 1. *The state-level upgrade of HIDZ can promote urban innovation efficiency, and this promotion has a dynamic effect. That is, with the implementation of the state-level upgrade policy, the urban innovation efficiency will be gradually strengthened.*

2.2. The Influence of Scientific Research Level of Local Higher Education Institutions

As state-level HIDZ gathers a large number of knowledge and technology-intensive high-tech industries and undertakes the mission of transforming scientific and technological achievements; they often have a close relationship with local universities and other research institutes. The scholars also regard whether it nears colleges and universities as the main principles for the location of HIDZ (Kihlgren, 2003) [23]. Many state-level HIDZ are indeed located in cities with more universities and other research institutions. One example is Silicon Valley, which is located around several top American universities with strong scientific research abilities, including Stanford University and the University of California, Berkeley. Another one is Zhongguancun, known as the "Silicon Valley of China", which also has nearly 41 universities represented by Peking University and Tsinghua University.

Compared to the born state-level HIDZ, the upgraded ones often face a sudden increase in the demand of scientific and technological talents and achievements, which are largely determined by the scientific research level of higher education institutions in the located cities. Therefore, it has an important impact on the relationship between the state-level HIDZ and regional innovation efficiency, which has also attracted the attention of some scholars. For example, Anselin, et al. (2000) found that the research activities of colleges and universities have obvious knowledge of a spillover effect on the high-tech industries in the region [24]. Slavtchev's (2007) findings showed that the quality and concentration of academic research in universities have a significant impact on regional innovation [25]. Meanwhile, colleges and universities are the main bodies of basic research, which is an important precondition for the development of applied research and experiments. Knowledge of the spillover effect of basic research can effectively reduce enterprise R&D cost to spur innovation, which in turn has a positive impact on the output and efficiency of regional innovation.

Therefore, the paper will further study the heterogeneity impact of the scientific research level of higher education institutions in the cities. According to previous reasoning, the paper proposes the following:

Hypothesis 2. *The higher the scientific research level of higher education institutions in the cities, the greater the promotion effect of the upgraded state-level HIDZ on urban innovation efficiency.*

3. Research Design

3.1. PSM-DID Model

PSM-DID method is used in the paper in order to effectively avoid the interference of sample selection bias and endogenous problems.

First, matching variables are selected, which are also called covariates. Caliendo and Kopeinig's (2008) stated that only variables affecting both outcome variables and the probability of policy implementation should be included in the PSM model [26]. Therefore, the variables that affect both the state-level upgrade of HIDZ and urban innovation efficiency are selected. They are as follows: economic development level (*lnpgdp*), industrialization level (*industry*), industrial structure (*thirdindustry*), science and technology input intensity (*scitechinput*), education input intensity (*eduinput*), openness level (*fdi*), level of higher education (*edu*), proportion of scientific and technical personnel (*sciemp*), and infrastructure condition (*inform*).

Second, the propensity score is calculated, which equals the probability that the province-level HIDZ in the city would be state-level upgraded. The Logit Regression Model is established, as shown in formula (1), where the dependent variable is a binary dummy variable (the city with the upgraded high-tech zone is taken as 1, the opposite is taken as 0), and the independent variables are the selected nine covariates. According to the results estimated by formula (1), the k-neighborhood matching method is used to match the treatment cities with the control cities within the common value range.

$$\begin{aligned} &Logit(treated_{it} = 1) \\ &= \varphi(lnpgdp, industry, thirdindustry, scitechinput, eduinput, fdi, edu, sciemp, inform) \end{aligned} \tag{1}$$

At last, the *treated* and control cities are further divided into four groups according to the time of state-level upgrade policy. The first and second group include the *treated* cities before and after the upgrading of the zone, and the third and fourth group are the control cities before and after the upgrading of the zone. Then, two dummy variables *treated* and *dt* are used to distinguish the above four sub-samples, and DID model are developed as shown in Equation (2):

$$Y_{it} = \delta_0 + \delta_1 treated_{it} + \delta_2 dt_{it} + \delta_3 treated_{it} \times dt_{it} + \delta_3 Z_{it} + \varepsilon_{it} \tag{2}$$

where Y denotes urban innovation efficiency, and *treated* is the dummy variable of whether there is an upgraded state-level NHTZ in the city (*treated* = 1 means there is, *treated* = 0 means the opposite). *Dt* is the time dummy variable (*dt* = 0 means the time before the upgrade of the zone, *dt* = 1 means the opposite). And *treated* × *dt* is the interaction of the two dummies, Z is a series of control variables, ε is a random disturbance term, and subscripts i and t mean the i-th prefecture-level city and the t-th year, respectively.

The meaning of each parameter in the above model is shown in Table 1. The net effect of the upgraded state-level HIDZ on urban innovation efficiency δ_3 can be examined by using PSM-DID method. If δ_3 is significantly positive, it indicates that the upgraded state-level HIDZ can promote urban innovation efficiency.

Table 1. Meaning of each parameter in the DID model.

	Before the Upgrading of the Zone (*dt* = 0)	After the Upgrading of the Zone (*dt* = 1)	Difference
Cities in the treatment group (*treated* = 1)	$\delta_0 + \delta_2$	$\delta_0 + \delta_1 + \delta_2 + \delta_3$	$\Delta Y_1 = \delta_2 + \delta_3$
Cities in the control group (*treated* = 0)	δ_0	$\delta_0 + \delta_2$	$\Delta Y_0 = \delta_2$
DID	-	-	$\Delta\Delta Y = \delta_3$

3.2. Sample and Data

As shown in Table 2, from 2009 to 2012, the State Council of China approved 51 upgraded state-level HIDZ in total. There were 27 province-level HIDZ upgraded in 2010, initiating a large-scale state-level upgrade. Therefore, the paper takes the state-level upgrade of HIDZ in 2010 as a quasi-natural experiment to examine the policy effect. The investigation period was from 2007 to 2015. The city-level panel data are obtained from the China City Statistical Yearbooks, the National Intellectual Property Office (SIPO) website, and the website of each city's statistics bureau.

The paper cleans data in the treatment group with the following steps: First, the cities which cannot be located in prefecture-level ones are excluded. Yanji is the capital of the autonomous prefecture, and Changji is a county-level city; thus, the two cities are excluded. Second, the prefecture-level city Suzhou, which has already had a state-level HIDZ before 2010 is excluded. Suzhou has an upgraded state-level HIDZ (i.e., Kunshan HIDZ) in 2010, but has already established a state-level Suzhou HIDZ as early as 1992. In the end, 24 prefecture-level cities with upgraded state-level HIDZ in 2010 are reserved in the treatment group.

To clean data in the control group, the paper firstly excludes the prefecture-level cities with state-level HIDZ as of 2015. Secondly, the prefecture-level cities without province-level HIDZ, ETDZ or industrial parks in the China Development Zone Audit Announcement Catalogue (2006 edition) are excluded. Because state-level HIDZ are not necessarily upgraded from province-level HIDZ. For example, Yingtan HIDZ in Jiangxi Province is upgraded from Yingtan Province-level Industrial Park. The predecessor of Suizhou State-level HIDZ is the Suizhou Province-level ETDZ, which was renamed the HIDZ one year before the state-level upgrade. Finally, 140 cities are kept in the control group.

Given that the approval time for the state-level upgrade of HIDZ in 2010 is concentrated on September and November, the paper uses 2011 as the time point for the implementation of the upgrade policy. That is, 2007–2010 is the time interval before policy implementation, and 2011–2015 is the time interval after the policy implementation. The paper only uses the data from 2007 to 2010 to conduct the group matching. Additionally, all of the variables' values are deflated by the GDP index in 2007 to eliminate the impact of inflation.

Table 2. State-level HIDZ upgraded from 2009 to 2012.

Year	State-Level Upgraded HIDZ	Amount
2009	Taizhou Medicine, Xiangtan	2
2010	Tangshan, Yanjiao, Yantai, Jining, Kunshan, Shaoxing, Quanzhou, Dongguan, Zhaoqing, Jiangmen, Wuhu, Bengbu, Yichang, Xinyu, Jingdezhen, Anyang, Nanyang, Weinan, Baiyin, Changji, Yinchuan, Qinghai, Liuzhou, Yingkou, Liaoyang, Yanji, Qiqihar	27
2011	Shanghai Zizhu, Yiyang, Linyi, Zigong, Jiangyin	5
2012	Wenzhou, Ma'anshan Cihu, Putian, Yingtan, Hengyang, Tai'an, Xinxiang, Xiaogan, Leshan, Yuxi, Benxi, Yulin, Xianyang, Changchun Jingyuee, Xuzhou, Wujin, Chengde	17

Note: The main data sources are the website of China Development Zone (http://www.cadz.org.cn/) and China Torch Statistical Yearbooks.

3.3. Main Variables

3.3.1. Dependent Variables

The input-oriented BCC model of data envelopment analysis (DEA) is adopted to measure urban innovation efficiency by using MATLAB 2016b [27]. Two variables in terms of expenditure of science & technology, and practitioners of scientific research & technical services are selected as the input indicators. The number of patent applications of the city is selected as the output indicator. Compared with patent grants, the number of patent applications is less sensitive to the government sector, and thus it can be used as a more suitable indicator to measure the true level of technological innovation in a city [28,29]. Considering the possible lag effect [30,31], the paper will investigate the urban innovation efficiency without lag, with a lag of 1 year and 2 years, respectively.

3.3.2. Independent Variables

The independent variables in the paper include the dummy variable of whether the state-level upgrade policy is implemented (*treated*), and the time dummy variable (*dt*) before or after policy implementation, as well as the scientific research level of higher education institutions in the cities.

3.3.3. Control Variables

All of the covariables in the PSM model will have an impact on urban innovation efficiency, and thus become the control variables in the DID model, which will not be repeated here.

The main variables and their calculation methods can be summarized as in Table 3. Table 4 indicates the descriptive statistics of these variables.

Table 3. Main variables and calculation.

Types	Variables	Variable Meaning	Calculation
Dependent Variable	*Y*	Urban innovation efficiency	The input-oriented BCC model of DEA
Independent Variables	*treated*	Whether the HIDZ in the city is an upgraded one	Dummy variable (0,1)
	dt	Before or after upgrading HIDZ	Dummy variable (0,1)
Covariates/control variables	*lnpgdp*	Economic development level	The logarithm of real GDP per capita
	industry	Industrialization level	(Regional secondary industry output value/regional GDP) × 100
	thirdindustry	Industrial structure	(Regional tertiary industry output value/regional GDP) × 100
	scitechinput	Science and technology input intensity	(Science and technology investment in public finance/regional GDP) × 100
	eduinput	Educational input intensity	(Education investment in public finance/regional GDP) × 100
	fdi	Level of openness	(The actual use of foreign direct investment in the region/regional GDP) × 100
	edu	Level of higher education	(Number of students in regular higher education institutions/total registered population at the end of the year) × 10,000
	sciemp	Proportion of scientific and technical personnel	(Scientific research and technical service practitioners/total registered population at the end of the year) × 10,000
	inform	Infrastructure level	(Total income of post and telecommunications business/regional GDP) × 100

Notes: The actual utilized FDI is converted into RMB at exchange rate of the current year.

Table 4. Descriptive statistics of main variables.

Variables	Observations	Mean	Std	Minimum	Maximum
Y	477	0.188	0.162	0.040	1.000
lnpgdp	477	10.242	0.627	8.742	12.420
industry	477	53.465	8.701	31.040	74.730
thirdindusy	477	35.173	7.169	17.240	53.750
scitechinput	477	0.201	0.131	0.019	1.032
eduinput	477	2.714	1.129	0.000	6.852
fdi	473	2.278	1.889	0.013	11.541
edu	475	135.469	103.130	17.482	587.796
sciemp	477	17.052	33.124	1.160	663.050
inform	475	2.451	1.645	0.343	11.007

4. Empirical Analysis

4.1. Policy Effect of Upgraded State-level HIDZ on Urban Innovation Efficiency

4.1.1. Analysis of PSM Results

There are 24 cities in the treatment group and 140 cities in the control group being matched by the method of k-proximity matching, and the best effect is then obtained when k equals 4. At the end, there are 22 cities in the treatment group and 31 cities in the control group being matched. The matching results are shown in Table 5.

Table 5. PSM matching results.

Group	Cities
Treatment group	Tangshan, Langfang, Yingkou, Shaoxing, Bengbu, Quanzhou, Jingdezhen, Xinyu, Yantai, Jining, Anyang, Nanyang, Yichang, Jiangmen, Zhaoqing, Dongguan, Liuzhou, Liaoyang, Qiqihar, Weinan, Xining, Yinchuan
Control Group	Luan, Yulin, Qujing, Baise, Tongchuan, Shangqiu, Liupanshui, Zhoukou, Xianning, Shaoguan, Mudanjiang, Rizhao, Jinzhong, Binzhou, Jincheng, Ezhou, Jiujiang, Hebi, Wuhai, Luohe, Huangshi, Huai'an, Qinhuangdao, Sanmenxia, Dandong, Huangshan, Jinhua, Fushun, Panjin, Zhoushan, Tongling

The results of the balance test are shown in Table 6. It shows that the standard deviations of all variables are less than 10% after matching, except *scitechinput*, *fdi*, *edu* and *inform*, whose standard deviations are slightly more than 10%. However, according to Rosenbaum and Rubin (1985), the matching method can be considered suitable and the estimation results are reliable when the absolute value of variables' standard deviations are significantly less than 20 after matching [32]. Meanwhile, no significant *t* statistics after matching indicates that there are no significant differences between the matched treatment group and the control group, which avoided the sample selection bias effectively.

Table 6. Balance test of PSM matching results.

Variables	Before/After Matching	Mean Value		Std (%)	Reduction of Std (%)	t-Statistics	t-Test P > t
		Treatment Group	Control Group				
lnpgdp	Before After	10.206 10.197	9.578 10.180	110.600 3.100	97.200	5.310 0.100	0.000 0.920
industry	Before After	54.320 54.000	47.639 53.756	74.000 2.700	96.300	2.970 0.090	0.004 0.927
thirdindustry	Before After	35.134 35.203	34.362 35.659	12.700 −7.500	41.000	0.540 −0.210	0.592 0.834
scitechinput	Before After	0.196 0.177	0.126 0.188	74.700 −11.600	84.400	4.130 −0.390	0.000 0.695
eduinput	Before After	2.072 2.097	3.215 2.187	−103.900 −8.2000	92.100	−3.980 −0.380	0.000 0.702
fdi	Before After	2.734 2.621	1.367 2.416	79.300 11.900	85.000	4.490 0.400	0.000 0.694
edu	Before After	151.110 133.790	64.210 123.510	96.400 11.400	88.200	5.650 0.440	0.000 0.662
sciemp	Before After	15.552 15.597	8.494 15.334	65.400 2.400	96.300	4.160 0.070	0.000 0.942
inform	Before After	3.235 3.203	3.301 2.938	−3.300 13.300	−300.800	−0.150 0.490	0.878 0.628

4.1.2. Analysis of DID Results

The results of DID regression are shown in Table 7. The dependent variables in Models 1 and 2 are urban innovation efficiency with no lag in output, while those in Models 3 and 4 and Models 5 and 6 are with a lag of 1 year and 2 years, respectively. According to the results of Models 1 to 6, the coefficients of the interaction (*treated* × *dt*) are all positive and significant at 1%. This shows that the state-level upgrade of HIDZ significantly improves the urban innovation efficiency. The results are proven to be robust to a certain degree due to a lack of significant differences in the policy effect of state-level upgrade, regardless of whether the output lag exists or how long the lag is.

Table 7. Impact of upgraded state-level HIDZ on urban innovation efficiency.

Independent Variables	Efficiency		Efficiency (1 Year Lag)		Efficiency (2 Years Lag)	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
treated	−0.035 * (−1.80)	−0.069 *** (−3.94)	−0.035 (−1.60)	−0.069 *** (−3.60)	−0.028 (−1.16)	−0.068 *** (−3.39)
dt	0.005 (0.32)	−0.047 * (−1.95)	−0.004 (−0.23)	−0.047 ** (−1.99)	−0.022 (−1.23)	−0.071 *** (−2.96)
treated × *dt*	0.088 *** (2.86)	0.098 *** (3.54)	0.094 *** (2.94)	0.103 *** (3.61)	0.098 *** (2.85)	0.110 *** (3.71)
lnpgdp		0.137 *** (3.62)		0.117 *** (3.19)		0.139 *** (3.69)
industry		0.000 (0.03)		0.002 (0.78)		0.002 (0.78)
thirdindustry		0.004 ** (2.01)		0.006 ** (2.53)		0.005 ** (2.22)
scitechinput		−0.187 *** (−2.81)		−0.186 *** (-2.81)		−0.170 *** (−2.77)
eduinput		0.030 ** (2.57)		0.026 ** (2.35)		0.029 *** (2.60)
fdi		0.009 ** (2.21)		0.010 ** (2.30)		0.011 ** (2.50)
edu		−0.000 (−0.76)		−0.000 (−0.39)		−0.000 (−0.41)
sciemp		−0.000 (−0.99)		−0.000 (−1.18)		−0.001 (−1.27)
inform		0.009 * (1.88)		0.010 * (1.94)		0.014 *** (2.64)
_cons	0.179 *** (13.92)	−1.418 *** (−4.46)	0.203 *** (13.90)	−1.311 *** (−4.37)	−0.223 *** (14.73)	−1.510 *** (−4.89)
N	477	470	477	470	477	470
R^2	0.036	0.233	0.032	0.214	0.027	0.233

Note: *, **, and *** indicate 10%, 5% and 1% significance levels, respectively.

According to the results of Models 2, 4, and 6, there are four control variables in terms of urban economic development level, industrial structure, infrastructure level, and the intensity of science and technology investment which have significant effects on urban innovation efficiency. However, the former three variables have a positive impact which is in line with expectations, while the impact of the last variable turns out to be negative, a result not as expected. The reasons may be as follows: On the one hand, government expenditure on science and technology stimulates the demand for R&D elements, while R&D resources are lacking supply elasticity because they are scarce in the short-term.

Thus, the price of R&D elements and then R&D cost of enterprises increases, which will bring a "crowding-out effect" to enterprise R&D activities and reduce innovation efficiency [33]. On the other hand, only when the government expenditure of science and technology breaks through a certain threshold does its positive effect on urban innovation gradually emerge [34].

As shown in Table 8, the paper further examines the dynamic effect of the upgraded state-level HIDZ on urban innovation efficiency; that is, whether the improvement of urban innovation efficiency is increasing in the implement process of the state-level upgrade of HIDZ. Specifically, the results of Models 2, 4, and 6 show that urban innovation efficiency has been significantly improved each year after the state-level upgrade of HIDZ, and the interactions' (*treated* × *dt*) coefficients tend to grow as time goes on from the 1st to 5th year. This indicates that the policy effect of the upgraded state-level HIDZ is gradually increasing over time; that is, the dynamic effect exists. Hypothesis 1 is supported.

Table 8. Dynamic effect of the upgraded state-level HIDZ on urban innovation efficiency.

Independent Variables	Efficiency		Efficiency (1 Year Lag)		Efficiency (2 Years Lag)	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
treated	−0.035 * (−1.79)	−0.069 *** (−3.92)	−0.035 (−1.59)	−0.068 *** (−3.58)	−0.028 (−1.15)	−0.068 *** (−3.36)
dt	0.005 (0.32)	−0.043 * (−1.75)	−0.004 (−0.23)	−0.044 * (−1.89)	−0.022 (−1.22)	−0.072 *** (−2.95)
treated × *dt1*	0.028 (0.64)	0.062 * (1.69)	0.052 (1.20)	0.083 ** (2.30)	0.072 (1.37)	0.109 ** (2.50)
treated × *dt2*	0.062 (1.28)	0.077 * (1.90)	0.074 (1.43)	0.089 ** (1.98)	0.059 (1.17)	0.077 * (1.84)
treated × *dt3*	0.080 (1.58)	0.093 ** (2.17)	0.045 (1.16)	0.057 * (1.67)	0.113 (1.95)	0.128 ** (2.44)
treated × *dt4*	0.082 * (1.77)	0.080 ** (2.11)	0.154 ** (2.42)	0.152 *** (2.66)	0.127 ** (2.06)	0.128 ** (2.45)
treated × *dt5*	0.188 *** (2.67)	0.181 *** (2.64)	0.144 ** (2.32)	0.135 ** (2.37)	0.118 ** (1.96)	0.107 ** (2.03)
control variables	*N*	*Y*	*N*	*Y*	*N*	*Y*
Y_cons	0.179 *** (13.86)	−1.359 *** (−4.16)	0.203 *** (13.84)	−1.279 *** (−4.24)	−0.223 *** (14.66)	−1.515 *** (−4.83)
N	477	470	477	470	477	470
R^2	0.040	0.248	0.050	0.224	0.033	0.235

Note: *, **, and *** indicate 10%, 5% and 1% significance levels, respectively.

4.2. Influence of Scientific Research Level of Local Higher Education Institutions

The data of the colleges and universities owned by the 22 cities in the treatment group are mainly collected from the official website of the Ministry of Education in China. According to the highest tier of the local colleges and universities, the 22 cities are divided into three groups. The first covers eight cities with first-tier universities; that is, cities with a high level of scientific research; the second group has nine cities with second-tier universities but no first-tier ones, which manifests a moderate level of scientific research; the last group possesses five cities with only third-tier universities or junior colleges, which expresses a low level of scientific research. Subsequently, further DID examination is conducted on whether the policy effect of the upgraded state-level HIDZ varies with a scientific research level of local universities and colleges, the results of which are shown in Table 9.

Table 9. Influence of scientific research level of local higher education institutions.

Independent Variables	High		Moderate		Low	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
treated	0.014 (0.30)	−0.063 ** (−2.04)	−0.057 *** (−3.22)	−0.050 *** (−3.23)	−0.044 ** (−2.40)	−0.053 *** (−2.59)
dt	0.005 (0.32)	−0.045 * (−1.90)	0.005 (0.32)	0.021 (1.08)	0.005 (0.32)	0.035 ** (1.96)
treated × *dt*	0.167 ** (2.17)	0.192 *** (3.42)	0.088 *** (2.74)	0.071 ** (2.36)	−0.006 (−0.27)	−0.021 (−0.99)
lnpgdp		0.140 *** (3.64)		0.010 (0.34)		−0.022 (−0.79)
industry		−0.001 (−0.40)		0.004 ** (2.17)		0.004 ** (2.14)
thirdindustry		0.003 (1.28)		0.008 *** (3.26)		0.006 ** (2.47)
scitechinput		−0.225 *** (−3.34)		−0.237 *** (−2.82)		−0.263 *** (−3.23)
eduinput		0.032 *** (2.59)		−0.003 (−0.31)		−0.010 (−1.10)
fdi		0.018 *** (3.06)		0.004 (0.86)		−0.001 (−0.17)
edu		−0.000 (−0.89)		−0.000 (−0.18)		0.000 (1.13)
sciemp		−0.000 (−1.15)		−0.000 (−0.91)		−0.000 (−0.93)
inform		0.008 (1.33)		0.004 (0.86)		0.000 (0.08)
_cons	0.179 *** (13.90)	−1.369 *** (-4.44)	0.179 *** (13.91)	−0.362 (−1.63)	0.179 *** (13.89)	0.020 (0.10)
N	333	329	378	373	324	318
R^2	0.093	0.290	0.032	0.128	0.019	0.130

Note: *, **, and *** indicate 10%, 5% and 1% significance levels, respectively.

According to the results of Models 2 and 4, in the cities with a high level of scientific research, the policy effect of upgraded state-level HIDZ is stronger than that of cities with a moderate level. The results of Model 6 show that the state-level upgrade of HIDZ in the cities with a low scientific research level have no significant policy effect. Therefore, the level of scientific research of the colleges and universities in the cities does strengthen the positive effect of the upgraded state-level HIDZ on urban innovation efficiency. Hypothesis 2 is supported.

5. Conclusions and Discussion

Based on the panel data of Chinese prefecture-level cities from 2007 to 2015, taking the large-scale state-level upgrade of HIDZ in 2010 as a quasi-natural experiment, the paper uses the PSM-DID method to examine the impact of the upgraded state-level HIDZ on urban innovation efficiency and its dynamic effect. In addition, heterogeneity analysis based on the scientific research level of local higher education institutions in the cities is conducted. The conclusions are as follows: First, the upgraded state-level HIDZ has significantly promoted the urban innovation efficiency, the positive effect gradually being strengthened with the implementation of the state-level upgrade policy. Second, the higher the scientific research level of higher education institutions in the cities, the greater the positive policy effect of upgraded state-level HIDZ.

Urban innovation efficiency is an appropriate indicator to evaluate fulfillment of the state mission of state-level HIDZ. Compared to the born state-level HIDZ, the upgraded one faces more significant opportunities and challenges. Therefore, evaluating the policy effect of the upgraded state-level HIDZ from the perspective of urban innovation efficiency, the paper not only fills a gap left by previous studies which have focused mostly on the total or originally established state-level HIDZ, but also evaluates the state-level upgrade policy more accurately, thus providing more effective support for policy adjustment or optimization.

Conclusions of this paper offer two policy implications: First, the state-level upgrade policy of province-level HIDZ should be unswervingly implemented in China. Although the performance of the upgraded state-level HIDZ is weaker than the born ones due to many developmental challenges, their policy effect on urban innovation efficiency is a significant positive. Additional reasons include the following: On the one hand, the state-level upgrade is a strategic arrangement for optimizing the spatial layout of HIDZ, and it will help to speed up the development of cities with weaker growth (e.g., some resource-based cities, western cities, and other poor or border cities), thus promotes coordinated regional development. On the other hand, the state-level upgrade is also an incentive and "spur" for province-level HIDZ. Before the upgrade, the province-level HIDZ will be encouraged to make it eligible for state-level upgrading. After the upgrade, the upgraded state-level HIDZ will be spurred to grasp huge opportunities as they ensue, making good use of the latecomer's advantages to fulfill the mission of leading innovation and promoting balanced development.

Second, the scientific research level of the higher education institutions in the cities should be considered in the development of the upgraded state-level HIDZ, as well as the qualification assessment of the province-level HIDZ to upgrade. On the one hand, for the existing upgraded state-level HIDZ, in addition to taking better advantage of the state-level identity based on their own characteristics, local governments should also pay attention to the cultivation of scientific research capabilities of higher education institutions in their cities. In this way, the innovative factors such as talents and achievements in scientific research will be continuously prepared for the upgraded state-level HIDZ to boost their real upgrade. On the other hand, for the province-level HIDZ who intends to apply for state-level upgrade in China, except for the economic performance and development potential, the scientific research level of the local higher education institutions should also be included in the evaluation criterion of the upgrade qualification. Thus, in order to upgrade the province-level HIDZ, the local governments would be motivated to raise the scientific research level of higher education institutions in the cities, and this will help to achieve a virtuous cycle of regional innovation and development [35].

There are also several limitations in the paper that future research can address. First, this paper's focus is on the state-level upgrade of HIDZ in 2010, while there are more than 100 HIDZ that were upgraded in batches since 2009. Future research can further expand the sample to evaluate the policy effect comprehensively based on the data from all of the upgraded state-level HIDZ in China. Second, due to the problem of data availability, the paper does not conduct empirical examination on the mechanism of how the upgraded state-level HIDZ affects urban innovation efficiency. Future work can further optimize research design and provide empirical support for the impact mechanism. Finally, as elaborated in the report of the 19th National Congress of the Communist Party of China, it is necessary to build a coordinated pattern of regional development based on city clusters. Therefore, the policy effect of the establishment and upgrade of HIDZ can further be evaluated at the dimension of city clusters [36].

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