The Validation of Sponge Cities Promoting the Co-Development of Economy and Ecology Based on the Quasi-Natural Experiment of 268 Cities

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Abstract: Based on the panel data of 268 cities in China from 2011 to 2019, this paper constructs a multi-dimensional measurement system of urban ecological quality and green economy level, and evaluates the effect of sponge city policy construction by using the double difference method after. The research shows that the construction of sponge city has a influence on promoting the development of urban ecological level and the level of green economy. The effect test shows that sponge cities mainly improve the ecological quality and promote economic development by promoting green technology innovation and improving the degree of government intervention to achieve policy effects. Therefore, we should vigorously promote the pilot construction of sponge cities, encourage scientific and technological innovation, pay attention to regional common development and expand the scope and depth of sponge city application in due time.

Keywords: Sponge city; Urban ecological level; Green technology innovation; Green economy; Quasi-natural experiment

1 Introduction

Sponge city (SC) is a modern urban construction concept, which means that rainfall and flood management systems can be established like a sponge to absorb, purify, and utilize water resources to systematically solve the problem of urban flooding. The current study evaluated the policy effects of SC, developed a mediating model to describe how SC promotes urban development, and discovered the ecological spatial spillover effects of SC policies.

SC can effectively prevent urban flooding while reducing other natural disasters. Based on this, this study proposes hypothesis 1.

H1: SC construction is conducive to improving the urban ecological environment and green economy

SC drive the development of green industries and enhance ecological resilience by establishing an innovation platform for environment-related technologies[1]. In addition, the government supports green industries through increased investment in environmental protection, fiscal-monetary policies, and administrative approaches (e.g., strict emission standards and

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enforcement for highly polluting firms) to reduce pollution and improve ecological quality at the production stage. Based on this, this study proposes hypothesis 2.

H2: SC improves the quality of the environment through green technology innovation and local government intervention.

2 Research design

2.1. Model setting

The experimental group of this paper is determined to be included in the pilot city. Other cities are defined as control groups. This study established the following benchmark model based on the design ideas of predecessors[2]:

$$ECO_{it}(GTFP_{it}) = \beta_0 + \beta DID_{it} + \beta_1 X_{it} + \eta_t + \nu_i + \varepsilon_{it} \quad (1)$$

As shown in model (1), ECO_{it} and $GTFP_{it}$ are explained variables of this study, representing urban ecological quality and green development level respectively. i and t represent city individuals and time variables respectively. DID_{it} is the core explanatory variable of the model, representing the situation of city i in time t. If the city is in the pilot in year t it is assigned a value of 1, otherwise it is assigned a value of 0. β is the policy effect we're looking at. X_{it} controls for other variables that may affect urban resilience. η_t fixes the year effect. The ν_i fixes the individual effect. ε_{it} is a random error term.

2.2. Variable specification

2.2.1. Explained variable

Quality of ecological development. This study measured from ecological resource elements and ecological environmental response. Five indicators were selected from the availability and science of comprehensive data (see Table 3). Specifically, the entropy method is used to calculate the weight after the standardization of each index. Finally, the weight is multiplied by the index to get the ecological quality level (ECO).

Table 1. Quality of ecological development indicator system

Target layer	Dimension	Index	Attribute
Ecological environmental quality	Ecological resource elements	Water resources per capita (cubic meters)	+
		Green coverage rate of built-up area (%)	+
		Per capita green park area (square meters)	+
	Ecological environment response	Centralized sewage treatment rate (%)	+
		Area of soil and water loss (square meters)	-

Green economy level. Based on the previous total factor productivity, green total factor productivity deeply considers the input of production factors and the consumption of energy resources. The input indexes in this paper are divided into capital input of fixed investment, labor input of employed personnel and energy consumption of total electricity consumption. Output indicators are divided into expected output and undesirable output. Expected output is expressed in terms of urban GDP and deflated. The undesirable output mainly considers the damage of economic activities to the ecological environment. This study mainly includes three indicators: discharge of domestic sewage, discharge of industrial waste 656 water and discharge of soot (ash).

2.2.2. Core explanatory variable

This paper takes the sponge city pilot policy as the core independent variable.

2.2.3. Mediating variable

The mediating variables established in this paper are green technology innovation and government intervention. In this study, the logarithm of the number of green invention patent applications and the proportion of public financial expenditure in local GDP were calculated respectively.

2.2.4. Control variable

Some characteristic variables that may have an impact on urban ecology and economy are introduced to control in this paper, mainly including original economic base, population density, education level, foreign direct investment, industrial rationalization level and annual precipitation[3].

2.3. Data source and processing

The annual precipitation in this paper comes from the surface climate section of the National meteorological Science data sharing service platform, and the original data of the invention patent comes from the National Intellectual Property Office. Other relevant data were collected from the China City Statistical Yearbook and statistical reports of various cities from 2011 to 2019.

Table 2. Descriptive statistics of variables

	Variable name	Mean	Std	Min	Max
Explained variable	Quality of ecological development(ECO)	0.057	0.071	0.011	0.723
	Green total factor productivity(GTFP)	1.009	0.029	0.960	1.060
Core explanatory variable	Whether to implement sponge city(DID)	0.033	0.179	0.000	1.000
Mediating variable	Green technology innovation(Green)	7.298	1.770	0.693	12.026
	Degree of government intervention(Gov)	0.110	0.084	0.002	0.364
Control variable	Primitive economic basis(GDP per)	10.713	0.571	8.773	13.056

Population density(Den)	5.767	0.927	1.609	7.882
Educational level(Edu)	10.416	1.211	5.920	13.207
Foreign direct investment(Fdi)	0.003	0.003	0.000	0.030
Industrial rationalization level(Ind)	0.359	4.213	0.000	206.93
Natural condition(Rain)	9.127	0.471	7.594	10.167

3 Empirical analysis

3.1. Reference regression test

In this paper, the impact of sponge city construction on urban ecological and economic benefits is evaluated by regression using difference-in-differences model. The results of baseline regression are shown in Table 3.

Table 3. Difference-in-differences model regression results

Variable	Column (1)	Column (2)	Column (3)
DID	0.017*** (0.008)	0.020*** (0.0264)	0.015** *(0.029)
lnGDP	0.062** (0.019)		-0.015 (0.014)
lnDen	-0.018 (0.084)		-0.053 (0.073)
lnRain	0.031*** (0.015)		-0.013 (0.035)
lnEdu	0.318** (0.140)		0.097*** (0.094)
Fdi	2.178** (0.856)		0.286 (0.461)
Ind	0.018*** (0.006)		0.004* (0.005)
Urban effect	YES	YES	YES
Time effect	YES	YES	YES
R^2	0.425	0.331	0.512

Note: *** *** means significant at 10%, 5% and 1% deciles respectively, standard error in parentheses, same as below

The result in column (1) is the regression situation after adding seven control variables such as economic base and population density. The estimated results showed that the regression coefficient of DID was still significantly positive ($\beta = 0.017$, $p < 0.01$), indicating that the results are reliable. Similarly, through the regression results of columns (2) and (3), it can be found that sponge city has a significantly positive effect on promoting the development of green economy regardless of whether control variables are added. Overall, the average effect of the pilot on improving urban ecological quality and economic level is 0.017 and 0.015, respectively. The policy effect is obvious, hypothesis 1 is verified.

3.2. Robustness test

3.2.1. Parallel trend test

The premise of using differential difference is that the experimental group and the control group maintain the same trend of change before receiving the policy shock. In this study, a time trend chart was drawn to observe the difference between the two groups of dependent variables. As shown in Figure 1, before the sponge city policy was implemented in 2015, the mean value of explained variables in the experimental group and the control group maintained almost the same trend of change.

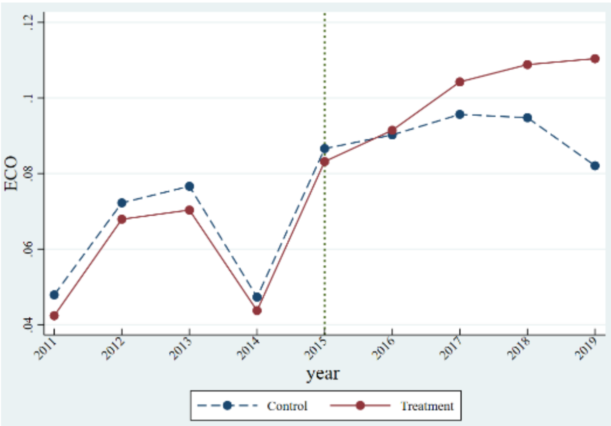

Figure 1. Parallel trend test diagram

3.2.2. Substitute key variable

This paper selects the comprehensive evaluation index of urban ecological economy as the proxy variable to carry out the benchmark regression. Specifically, the entropy method is used to calculate the weight of indicators and sum up to get the scores of each city. Then regression was carried out according to model (1). The final results are shown in Table 5, which once again proves the robustness of the benchmark regression results of this study.

Table 4. Regression results of replacement explained variables

	Eco-economic			
Variable	(5)	(6)	(7)	(8)
DID	0.010^{*}	0.012^{**}	0.019^{***}	0.021^{***}
	(0.011)	(0.005)	(0.012)	(0.008)
Urban effect	NO	YES	YES	YES
Time effect	NO	NO	YES	YES
Control variable	NO	NO	NO	YES
R^2	0.222	0.241	0.331	0.352

3.2.3. Placebo test

This paper adopts random sampling strategy to conduct placebo test on the policy effect of sponge city. In the 500 samples randomly selected for regression, only 9 sampling results had an estimated coefficient greater than the ECO estimated coefficient in the baseline regression (0.017). This means that in random extraction, the probability of the estimate being greater than 0.017 is only 1.8%[4]. This is a small probability event. Similarly, in 500 sample tests of green total factor productivity (GTFP), only one result was greater than the baseline regression coefficient (0.015). This also fully proves that the baseline regression results are not affected by other uncontrollable factors.

Table 5. Placebo test table

Explained variable	**ECO**	**GTFP**
Reference regression coefficient	0.017	0.015
Higher coefficient sample	9	1
Sample with a lower coefficient	491	499
Two-sided test for P values	0.036	0.004
Sampling frequency	500	

4 Influence mechanism test

In order to verify the mediation mechanism, the following test model is proposed by referring to the sequential test method：

$$ECO_{it}(GTFP_{it}) = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 X_{it} + \alpha_3 M_{it} + \eta_t + \nu_i + \varepsilon_{it} \quad (2)$$

$$M_{it} = \theta_0 + \theta_1 DID_{it} + \theta_4 X_{it} + \eta_t + \nu_i + \varepsilon_{it} \quad (3)$$

Among them, the intermediary variable is M_{it}, namely the level of urban green technology innovation and the degree of government intervention.

Table 6. Test table of the mediating effect of green technology innovation

Variable	**ECO**		**GTFP**	
	(13)	(14)	(15)	(16)
	$Green$	ECO	$Green$	$GTFP$
DID	0.362^{***}(0.107)	0.021^{***} (0.008)	0.149^{**} (0.012)	0.019^{***} (0.029)
$Green$		0.005^{**} (0.003)		0.010^{**} (0.003)
Urban effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes
R^2	0.313	0.411	0.509	0.622

First, the mediating effect of green technology innovation is tested, and the results are shown in Table 8. In column (13), sponge city construction effectively drives the development of urban green technology innovation (θ_1=0.0122，$p < 0.01$). In column (14), both sponge city and green technology innovation have significantly positive effects on ecological quality. By promoting green technology innovation and optimizing the industrial structure, sponge cities stimulate the vigorous development of green finance, green credit and other investment products, and strongly promote the progress of urban green economy[6].

Then the mediating role of government intervention is tested. The regression results are shown in Table 7. In column (17), sponge city construction effectively improves the degree of government intervention (θ_1=0.0122， $p < 0.01$). In Column (18), both sponge city and government intervention have significantly positive effects on Ecological environmental quality. According to Column (19) and (20), it is not difficult to find that sponge city construction increases ecological investment and green industry support by increasing the degree of government intervention, and effectively promotes the development of green economy.

Table 7. Test table of the mediating effect of government intervention

Variable	ECO		GTFP	
	(17)	(18)	(19)	(20)
	Gov	ECO	Gov	$GTFP$
DID	0.273** (0.111)	0.016** (0.012)	0.213*** (0.002)	0.029*** (0.009)
Gov		0.011** (0.005)		0.019** (0.004)
Urban effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes
R^2	0.211	0.312	0.498	0.509

5 Conclusion

The findings are as follows. Sponge city construction can improve urban ecological quality and promote the development of green economy to a certain extent. This conclusion remains true after a series of Robustness tests. By testing the mediating variables, this paper argues that sponge city can achieve the goal of ecological and economic development by promoting green technology innovation and improving the degree of government intervention.

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