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Does the Eutrophication Control Improve People's Utility: Evidence from the Second-Hand Housing Market and the Taihu Lake Sludge Removal Project

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Abstract:

Addressing water body eutrophication often requires substantial and long-term public expenditure. However, due to the public good (PG) nature of water management policies, there is limited research estimating the level of public support for such policies. In 2020, the Chinese government implemented a closed dredging project around the Taihu Lake basin in Wuxi, creating a potential natural experiment. This paper uses second-hand housing transaction data from Wuxi from 2017 onwards. By employing revealed preference and hedonic pricing models, to construct a difference-in-differences (DID) model, the paper evaluates the causal effect of the dredging policy on second-hand housing prices in the Binhu District, aiming to reflect the impact of the dredging policy on residents. The study finds that the eutrophication dredging policy significantly increased the second-hand housing prices by 8% on average in the affected areas, though the duration of this effect appears to be limited. This research provides valuable insights into the economic effects of environmental governance policies and considerations for future water quality management decisions by governments.

Keywords: Eutrophication; Urban Economics; DID; Policy Analysis; Hedonic Model.

1. Introduction

The United Nations defines water eutrophication as a severe water pollution event caused by excessive organic elements or nutrients in the water, leading to the overgrowth of algae or aquatic plants [1]. Eutrophication often results in significant algal blooms or red tides, where large quantities of phytoplankton not only produce toxic substances but also deplete dissolved oxygen in the water, causing massive deaths of aquatic animals like fish, creating anoxic "dead zones" [2, 3]. The contaminated freshwater becomes

foul-smelling and toxic, causing significant disruption to the lives of nearby residents and economic activities, particularly fisheries and tourism[4]. Addressing water eutrophication has long been a critical task worldwide, with well-developed solutions including bioremediation, chemical precipitation, photocatalytic oxidation, and aeration[1, 2]. Given the complex causes of eutrophication, often stemming from ongoing urban economic activities, managing eutrophication requires substantial long-term government investment [1].

However, behind this lies a more straightforward and crucial question: Do people support and recognize the policies to control water eutrophication? Or, from an economic perspective, does people' subjective utility increase due to water quality improvement policies? Due to the public good nature of water quality improvement policies and the lack of detailed data or quasi-natural experiments, there has been little empirical evidence to assess the impact of water treatment policies on people's utility.

Based on the second-hand housing market and a relatively unique water quality improvement policy in the Taihu Lake region of China, this paper attempts to reflect people's perceptions of water quality improvement policies from a new perspective. The underlying motivation is based on hedonic pricing theory, that in a free market, an improvement in a region's utility for people often leads to higher real estate valuations, increasing the prices of second-hand houses. This paper utilizes the 2020 dredging policy in Binhu District, Wuxi City, which rapidly improved the water quality of the coastal areas of Binhu District while having minimal impact on the water quality of surrounding similar urban areas. The research finds out that after the water quality improvement policy was implemented in Binhu District, local second-hand housing prices immediately experienced faster growth, indicating that people value water quality improvement policies. However, this effect seems to have faded within less than three years, possibly due to the population shift among districts after the policy, which overshadowed the effects of the dredging policy.

The remainder of this paper is organized as follows: Section II briefly reviews the history of eutrophication management in Wuxi and introduces the differences of the 2020 new policy. Section III discusses how the Hedonic Price Theory provides an economic explanation for the results designed by the Hedonic Regression Studies. Section IV introduces the data used for analysis, and Section V explains the econometric model employed in this paper. Section VI presents the empirical results. Section VII discuss the results and criticize the flaws of the study. Section VIII concludes.

2. Policy Review

Taihu Lake is one of the largest freshwater lakes in China and has long been a critical foundation and core pillar for economic activities in the Yangtze River Delta region [5]. However, in recent years, the rapid economic development in the Yangtze River Delta has led to the discharge of massive amounts of industrial wastewater, agricultural runoff, and domestic sewage into Taihu Lake, resulting in severe water eutrophication [6]. In 2007, Taihu Lake experienced a blue-green algae outbreak, an environmental disaster that severely impacted surrounding cities that relied on Taihu Lake as a drinking water source, including Wuxi and Suzhou, where the water supply was completely cut off [7].

In response, the central government, as well as various levels of the Jiangsu provincial government, significantly increased their focus on the water pollution issues of Taihu Lake and proposed a series of emergency and long-term policies to address the eutrophication problem. Since 2008, the Taihu Lake basin has been included in the national key river basin water pollution prevention and control plan during the 11th Five-Year Plan period [8]. Following this plan, Jiangsu Provincial Government continuously intensified its efforts to improve Taihu Lake's water quality. These efforts included shutting down and relocating numerous factories, implementing the "returning farmland to the lake" program, promoting the construction of domestic sewage treatment facilities, and regularly conducting blue-green algae removal operations each year[9].

Despite these efforts, the density of blue-green algae in Taihu Lake continued to rise, increasing pressure on the lake's management [10]. Wuxi City implemented a major sludge removal project in Binhu District to address this growing challenge in 2020 [11]. The total investment for this dredging project was approximately 3.6 billion RMB, targeting the removal of around 18 million cubic meters of sludge from key water areas along the coast of Binhu District, covering a total treatment area of about 80 square kilometers [12]. To minimize the disturbance, the dredging operations were conducted and closed, ensuring that the dredging project in Binhu District did not affect other areas [12]. After the dredging, the water quality in the lakes along the Binhu District improved rapidly, achieving a complete elimination of water quality worse than that of V River [13].

3. Using Hedonics to Value Changes in Local Environmental Quality Due to Dredging Policy

The impact of the Taihu Lake Dredging project is chal-

lenging to observe directly. This is partly because there is no transparent environmental cleanup market in Wuxi and partly because the improvement in Taihu Lake's water quality resembles a public good, where the affected groups are relatively broad and non-exclusive. However, the Hedonic Pricing Model can decompose the price of market goods (such as houses) into the value of their constituent characteristics, thereby indirectly reflecting the impact of non-market amenities on prices.

The Hedonic Model has a long history of estimating the relationship between housing prices and environmental amenities, but it has mainly been applied to cross-sectional data analysis so far [14]. But recently, study has shown that the Hedonic Model effectively analyses panel data when combined with the Difference-in-Differences approach, thereby eliminating endogeneity issues [14].

According to Rosen, in a classic Hedonic Model, this paper uses Equation (1) to probe the house price [15].

$$\max_{c,a_1,\ldots,a_n} u(c,a_1,\ldots,a_n) \, st. c + P(a_1,\ldots,a_n) = y \tag{1}$$

In Equation (1), c is a bundle of consumption goods other than housing, $u(c,a_1,\ldots,a_n)$ is the utility function of the consumer with respect to different dwelling characteristics (such as building size, construction year, and quality of surrounding schools), $P(a_1,\ldots,a_n)$ is the price function of housing composed of its various characteristics, and y represents the consumer's income constraint.

Here, the author adopts the separability assumption, which means that the consumer's choice regarding specific characteristics of goods will not affect their choice regarding other sets of goods or characteristics. By doing so, the author obtains Equation (2).

$$\max_{c,a_1,\ldots,a_n} c + u(a_1,\ldots,a_n) \, st. c + P(a_1,\ldots,a_n) = y \tag{2}$$

Based on Equation (2), if further assume that other variables, except water quality that could affect housing prices and utility within the model, remain constant. By doing so, the model could be simplified as shown in Equation (3).

$$\max_{c,w} c + u(w) \, st. c + P(w) = y \tag{3}$$

Where w refers to the water quality factor. To ensure that the maximum utility is obtained under the budget constraint, taking the partial derivative yields the Equation (4).

$$\frac{\partial u(w)}{\partial w} = \frac{\partial P(w)}{\partial w} \tag{4}$$

This will form a bid curve, an indifference curve that indicates the maximum price a second-hand homebuyer is willing to pay for a given water quality condition while keeping their utility level constant.

The previous occupants or owners of the housing constitute the supply side of the second-hand housing market. This paper assumes that the second-hand housing market is perfectly competitive, where each supplier sells second-hand houses with zero profit, denoted as π. The supplier's profit consists of two parts: the price equation of the second-hand house relative to various factors, and the other is the relative cost of these factors to the developer (for example, a location with a better surrounding environment usually implies higher land costs). Also, by applying the separability assumption, this paper derives the offer curve for characteristic w, as shown in Equation (5).

$$\pi = P(w) - Cost(a) \tag{5}$$

The bid curve from the demand side and the offer curve from the supply side is tangent at the point where the transaction price between an individual second-hand homebuyer and an individual second-hand house seller is determined for a given water quality w_i. At this point, the market reaches equilibrium. Since buyers and sellers are in the market with different utility and profit curves, collecting these equilibrium points forms the Hedonic Curve. Therefore, when taking environmental quality as the horizontal axis, the slope at each point on the Hedonic Curve represents the individual consumer's Willingness to Pay (WTP) for a specific level of environmental quality [15]. Thus, when local water quality improves, increasing potential utility, individual consumers would receive negative compensation to keep their utility unchanged. In other words, areas with higher water quality are likely to have relatively higher housing prices, which could be realized through consumer migration between regions.

Therefore, this paper proposes the following hypothesis: The commercial housing in Binhu District will receive a higher valuation after the 2020 Taihu Lake sludge removal project, and the growth rate of second-hand housing prices will outpace second-hand housing prices in the Xinwu District.

4. Data Sources

The initial data for this paper primarily comes from the transaction record database of second-hand housing provided by a third-party real estate service company [16]. This dataset includes detailed information such as property ID, neighbourhood, street, administrative district, housing type, transaction price, transaction date, building area, transaction cycle, building type, renovation status, and ownership type. The data is highly accurate and authoritative, thanks to its large sample size. Specifically, in processing the data, this paper randomly selects 20% of the sample from the dataset and filters out the second-hand housing information within the two administrative dis-

tricts that serve as the treatment and control groups. This approach ensures the randomness of the sample selection. After removing missing and anomalous data, the final panel data analyzed in this paper includes transaction information for 4,370 second-hand houses in Binhu District and Xinwu District of Wuxi City, covering seven years from 2018 to the present.

5. Econometric Methods

This paper employs the Difference-in-Differences (DID) method, using the 2020 dredging policy targeting the Taihu Lake waters surrounding Binhu District in Wuxi as a quasi-natural experiment, to explore the causal relationship between eutrophication control policies and changes in second-hand housing prices. By designating Binhu District, the area directly benefiting from the 2020 dredging policy, as the treatment group and the nearby Xinwu District, which was not significantly affected by the policy, as the control group, the author constructed the following high-dimensional regression model for the Difference-in-Differences analysis.

$$ln(P_{it}) = \alpha + \beta(td_t * dd_i) + \delta control + \mu_i + \gamma_t + \epsilon_{it} \quad (6)$$

In Equation (6), $ln(P_{it})$ represents the marginal price of second-hand housing obtained by taking the natural logarithm of the price function in the hedonic model. td_t is the treatment effect time dummy variable. Since the dredging policy in Binhu District was implemented in 2020, this paper considers 2020 as the year when the policy began to have an impact; specifically, 2021 and subsequent years are assigned a value of 1, while other years are assigned a value of 0. And dd_i is the treatment group dummy variable, indicating whether the property is located in the affected district; specifically, second-hand houses in the control group, Xinwu District, are assigned a value of 0, while those in Binhu District are assigned a value of 1. $td_t * dd_i$ is the interaction term of the Difference-in-Differences model used to assess the impact of the Taihu Lake dredging policy. To enhance the generalizability of the model and improve its credibility, this paper includes a series of control variables, including building area, number of bedrooms, and whether or not the dwelling has had refined decoration. A significant challenge in the regression process is the potential presence of many omitted variables not included in the model, which could lead to multicollinearity and endogeneity issues. To address this, this paper adopted two-way fixed effects in the regression to enhance the credibility of the results. Specifically, μ_i represents individual fixed effects controlled by the ID of different blocks, thereby accounting for unobserved factors such as the quality of nearby schools, public safety, and the reputation of developers in various blocks. γ_t is the time-fixed effect. ϵ_{it} is the random error term.

The most critical coefficient in this model is β, which represents the economic significance of "the impact of the Taihu Lake dredging policy on second-hand housing prices in the affected district."

6. Empirical Results And Implications

Table 1. Baseline Regression Analysis

	(1)	(2)	(3)	(4)
	ln_price	ln_price	ln_price	ln_price
DID	0.142**	0.099***	0.087**	0.085**
	(2.73)	(2.88)	(2.56)	(2.50)
_cons	4.858***	3.809***	3.633***	0.922***
	(267.82)	(96.72)	(72.80)	(10.86)
Year	YES	YES	YES	YES
Individual	YES	YES	YES	YES
Control bedroom		0.435***	0.174***	0.173***
		(27.42)	(9.31)	(9.26)
Control area			0.009***	0.009***
			(11.71)	(11.86)
Control fitment				0.064*
				(2.04)

N	4370	4369	4369	4369
R^2	0.295	0.634	0.734	0.735
adj. R^2	0.290	0.631	0.732	0.733

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

This paper estimates the impact of the dredging policy on second-hand housing transaction prices using a Difference-in-Differences (DID) model, with the estimation results shown in Table 1. Column (1) presents the baseline regression for housing prices in the treatment and control groups, controlling only for individual and time-fixed effects. Subsequently, Columns (2) to (4) progressively include control variables to make the regression model's estimates more robust.

The results in Table 1 indicate that the Taihu dredging project significantly increased second-hand housing transaction prices in the affected areas. After controlling for property characteristics, area, and renovation status, the policy led to an average price increase of 8.5% in Binhu District. The R^2 value reached 0.735, which means that the constructed regression model explains most of the variation in second-hand housing prices, demonstrating that the model has considerable credibility and completeness.

7. Robust Test

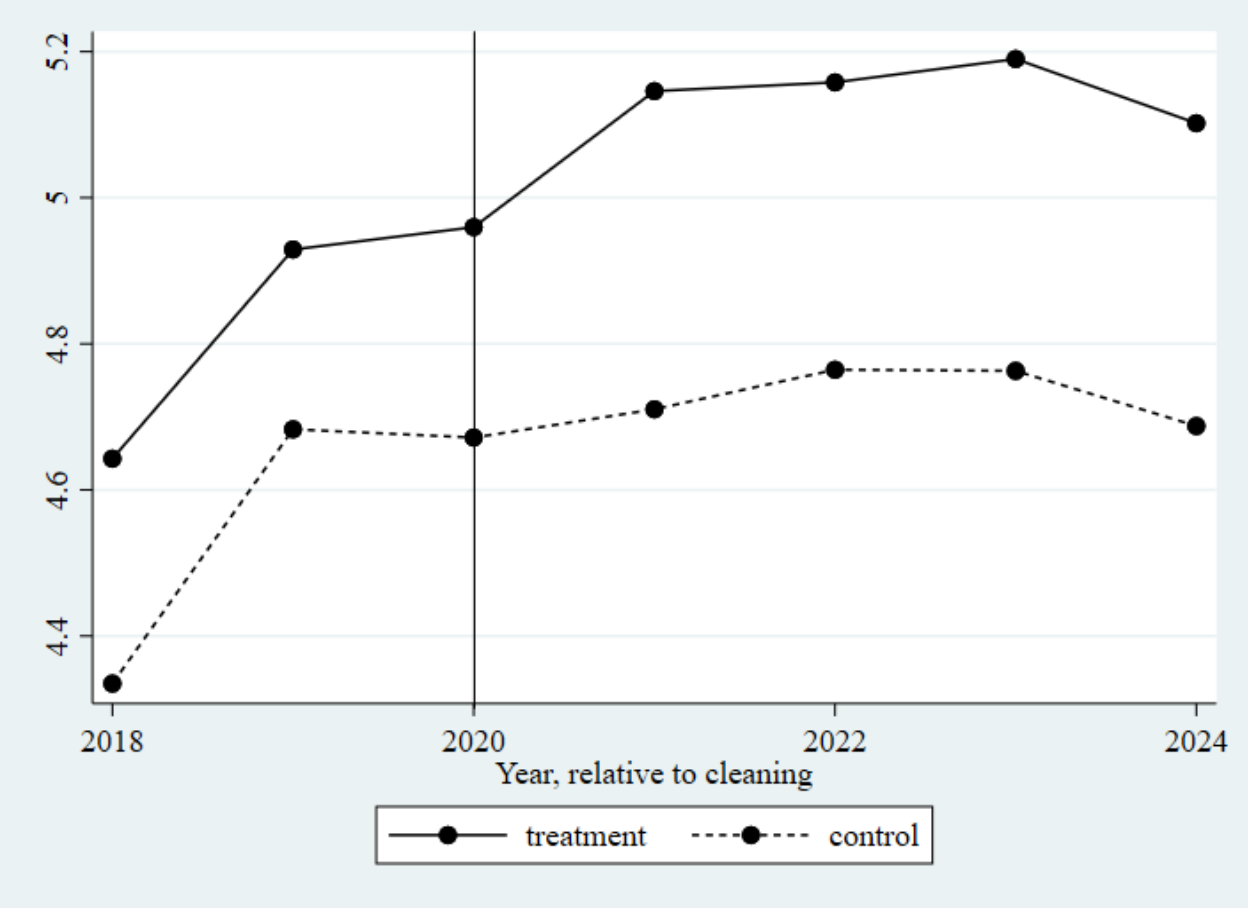

Fig. 1 Time Trend Graph of Second-hand Housing Prices Between the Treatment Group and Control Group

To ensure the robustness of the empirical results, this paper further conductes a parallel trends test. The paper refers to the practice of Qian et al., visualizing the annual average housing price trends in the treatment area (Binhu District) and the control area (Xinwu District) using log-transformed second-hand housing prices, as shown in

Fig.1 [17]. This figure intuitively reveals the differences in price trends between the two areas. Several important insights can be drawn from Fig.1:

Firstly, the second-hand housing price growth trends in the treatment and control groups remained parallel before the policy implementation, supporting the validity of using the Xinwu District's housing prices as a credible counterfactual for the Binhu District's second-hand housing market. This also indicates that the data meets the pre-trend assumption of parallel trends.

Secondly, in the year the dredging project was implemented, the price trends in Binhu District and Xinwu District diverged, with Binhu District experiencing an acceleration in second-hand housing price growth while Xinwu District showed signs of a slight slowdown. The price difference between the two areas gradually widened after the implementation of the dredging project. This further validates the positive impact of the lake dredging policy on second-hand housing prices, indicating that the price increase in Binhu District was indeed due to the improvement in water quality in the surrounding area.

Finally, the paper notes that the price trend difference between the treatment and control groups seems to disappear about three years after the dredging project was implemented. This suggests that the effects of the dredging policy may not be long-lasting.

8. Disscussion

Table 1's estimates indicate that after the implementation of the dredging project, housing prices in the affected Binhu District increased by 8.65% compared to the unaffected Xinwu District. This represents a significant change in housing prices. In contrast, the impact of the dredging policy is even more pronounced than that of the control variable related to renovation conditions, which is commonly believed to significantly affect housing prices. This suggests that people generally place considerable importance on the impact of environmental amenities on their quality of life. In this case, Taihu Lake is not only a tourist resource for residents of Binhu District but also a water source, which likely increases the significance of lake water management for them.

However, if this policy similarly affects the rental market, the dramatic impact of water quality improvement on living costs could lead to population migration between districts. Some residents of Binhu District, unable to afford the high housing or rental costs these days, might relocate to other districts (such as Xinwu District). Such population shifts could, in turn, increase housing prices in surrounding areas, potentially reducing the observable impact of the dredging policy on prices over time. In Fig. 1, the Difference-in-Differences between housing prices in Binhu and Xinwu Districts seems to converge three years after the policy implementation, likely due to this migration effect. This effect might reduce residents' utility, as many who move to other districts may still work in Binhu, resulting in wasteful commuting. Future research could explore this aspect in more detail, which could be crucial for government planning of water quality improvement projects and their implementation scope.

Finally, there are some limitations and gaps in this study. Firstly, the annual transaction volume of second-hand houses in Binhu and Xinwu Districts has fluctuated significantly over the years. This variability in transaction volume was not explicitly accounted for in the regression analysis. It is unclear whether these fluctuations could introduce bias in the results. Future research should consider including transaction volume as a variable in the analysis to control for its potential impact on housing prices.Additionally, this study utilized data from the entire district level for Binhu and Xinwu. A more refined approach might involve selecting the treatment and control groups based on the distance from residential areas to Taihu Lake. By focusing on communities closer to the lake compared to those farther away, it may be possible to establish a more precise comparison, yielding more reliable results regarding the localized impact of the policy.

9. Conclusion

In summary, this study offers preliminary evidence suggesting a significant promotion of the 2020 Taihu Lake sludge removal project on the second-hand housing market in Binhu District. The findings are encouraging but should be interpreted with caution due to the study's limitations. Future research should focus on accounting for transaction volume effects, refining geographic specificity, and conducting a cost-benefit analysis to provide more definitive insights. The paper could be helpful for drawing stronger policy implications and guiding future environmental management strategies effectively.

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