THE EFFECT OF REMEDIATING SEVERELY POLLUTED WATER BODIES:

EVIDENCE FROM HOUSING SALES IN SHANGHAI

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

Luming Tan

August 2021

ABSTRACT

Severely polluted water bodies have become a major issue in the urban environment. The Chinese government has made a lot of efforts to remediation black-odorous water bodies (BOWB) in urban areas since 2015. In order to measure the benefits brought by the remediation, I apply three Difference-in-Difference Hedonic Price Model to estimate the impacts of remediation, listing, and completion in Shanghai, combining the BOWB dataset and housing transaction dataset from 2015 to 2018. The findings reveal that the BOWB-affected distance is 0.7km. For housings located within 0.7km from a BOWB, their unit housing prices increase 11.6% on average after remediation, compared with housings located between 0.7 to 3km from a BOWB. Based on a back-of-envelop calculation, the overall benefit of BOWB remediation projects in Shanghai is 36 billion RMB.

BIOGRAPHICAL SKETCH

The author is from Guangzhou, China, and received her bachelor's degree in Economics and Environmental Analysis and Policy from Boston University in 2016. After graduation, she spent two years in World Wild Fund for Nature (WWF China) as a conservation program officer. Later, she decided to switch to the planning field and pursued her Master of Science in Regional Science at Cornell University.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1:

INTRODUCTION

With the rapid urbanization and development in China, environmental qualities such as water, air, and soil have significantly degraded. As the economic and financial center in China, Shanghai had also experienced environmental degradation since the opening form in 1978. The city is located at the estuary of the Yangtze River and crisscrossed by waterways. Rivers, canals, and ditches play an essential role in shaping Shanghai's city landscape and become a part of its culture. Thus, the degradation of water quality was undermining the city. Its water quality is majorly affected by the Yangtze River's upstream activities and the urbanization development. In 2015, the water quality of 56.4% of monitored river sections had a water quality inferior to Category V, which is the worst grade under the China Environmental Quality Standards for Surface Water and defined as essentially useless (Shanghai Municipal Bureau of Ecology and Environment, 2015).

To improve water quality, the Chinese government launched the Action Plan for Water Pollution Prevention and Control (the Action Plan) and the Work Guide for the Treatment of Black and Odorous Water Bodies in Cities (the Work Guide) in 2015. Black-odorous water body (BOWB), named after its blackened color and foul odor, is the signal of a severely polluted water environment. BOWBs harm human health and cityscape and pose both health and economic threats to nearby residents and pedestrians. Following the national Action Plan and Work Guide, the Shanghai government listed 56 BOWBs with either mild and severe levels at the end of 2015, and completed remediation of all BOWBs in December 2017.

Most of the BOWBs are located near the city center of Shanghai, which also has abundant and decent amenities such as schools, subways, and business centers. Thus, compared with properties far away from BOWBs, the properties near BOWBs may experience positive impacts from good amenities and adverse effects from BOWBs.

1

Commonly, the cost of improving environmental quality is measured indirectly by valuing a private good that is either a complement like recreation demand or a substitute like water filtration because environmental externalities do not have monetary markets. Existing methods of valuing willingness to pay (WTP) for water quality include travel cost method, stated and revealed preference methods, opportunity cost approach, and Hedonic Price Models (Kroes and Sheldon, 1988; Freeman, 1993; Phaneuf and Smith, 2005; Rosen, 1974; Roback, 1982). For example, the Ecosystem assessment Guidelines for Gross Ecosystem Product Accounting of Terrestrial Ecosystems adopts an opportunity cost approach to estimate the treatment cost of restoring certain volumes of water.

In this paper, I address two questions: 1) the BOWB-affected buffer; 2) the impact of BOWB remediation. To do so, I firstly employ the Local Polynomial Regression (LPR) approach developed by Linden and Rockoff (2008) to fit housing prices before and after the remediation to distances to the nearest BOWB and detect the point where the impact of BOWB vanishes. Based on this result, I am able to separate the housing transactions data into treatment group and control group and apply Difference-in-Difference Hedonic Price Models to quantify the impact of remediation, listing, and completion separately.

Hedonic Price Models, using a quality-differentiated method, regress housing prices on structural attributes (S), locational attributes (L), neighborhood attributes (N). Its coefficients reflect the marginal change of attributes of interest in the value of housing (Goodman, 1978). Therefore, by measuring the impacts of BOWBs before and after remediation on housing prices, I can quantify the benefit of remediation and thus the value of negative environmental externality brought by BOWBs. Many studies have explored quantifying the impacts of non-market goods, especially environmental goods using housing prices and Hedonic Price Models. The research topics covered range from air quality (Bajari et al., 2012; Freeman et al., 2019); shale gas development ((Muehlenbachs et al., 2015; Boslett et al., 2016); to cancer risk (Davis, 2004), etc. The applications of Hedonic Models on water quality are much fewer. One possible reason is that water quality, unlike air

2

quality, drilled wells, and other environmental goods, is hard to observe. Water quality indicators, like permanganate, ammonia nitrogen, and total phosphorus, cannot be perceived or observed until they cumulate to a certain level. Utilizing BOWBs as an indicator of water quality avoids this issue. Firstly, as defined in the Work Guide, BOWBs are water bodies that have unpleasant colors and (or) unpleasant odors. Also, as required by the Work Guide, BOWBs are identified not only based on traditional scientific indicators but also on public and experts' opinions.

To capitalize the benefit of BOWB remediation, I conduct a Difference in Difference Hedonic Price Model using individual housing transaction data from 2015 to 2018 in Shanghai and match them with 56 BOWBs using GIS. I assume that BOWB nearby housing prices are affected by BOWBs because BOWBs can be easily observed by nearby residents and so enter their utility function as aesthetic value, health risk, and environmental risk. The whole process of remediation can be divided into three phases: pre-listing, remediation, and post-completion. Based on this, I categorize the impacts of nearby BOWB remediation on housing values as follows:

> *Listing Effects.* – This category refers to the impact of listing BOWB on nearby housing values. Some nonmarket-valuation studies find that people's subjective perception is not consistent with their objective measures, and thus information disclosure may change people's MWTP (Boyd et al., 2015). The listing process surveyed nearby citizens and the listing results were disclosed to the public. Thus, it is reasonable to assume that the buyers and sellers of BOWB nearby housings were fully informed after the listing process. It is expected to see an adjustment in housing prices due to listing effects. The effects can be negative or positive depending on whether the futural expectation of better water quality outweighs the current lousy quality.

Completion Effects. – This category refers to the changes in housing values before and after the announcement of completing BOWB remediation. Similar to the listing process, the judgment of completion is based on scientific water quality indicators and satisfaction surveys on nearby residents. The completion results were reported on media. Thus, I assume that buyers and sellers are fully informed, and they will adjust the housing prices based on the remediation results. The completion effect is expected to be positive because, after the completion of the remediation, the water quality is significantly improved. The rivers' aesthetic value and ecosystem function will be restored while health risk and environmental risk brought by BOWBs will decrease.

Remediation Effects. – This category refers to the changes in housing prices before listing and after the announcement of completion. It is the overall effects covering the whole remediation process, including both listing and completion effects. Similarly, it is expected to be positive because BOWBs' negative externality is eliminated.

I apply a DID Hedonic Model for each effect separately. Same as traditional Hedonic Models, the structural attributes (S) include floor areas, number of bedrooms, number of bathrooms, floor level, equipped with elevators or not, face south or not, and year built. The locational attributes (L) contain distance to the nearest subway station, distance to the nearest school, school quality, distance to the nearest star-rated park, park star level, and distance to the CBD. Districts in Shanghai have different policies for housing markets, school districts, etc. The housing market usually experiences peak season in September and October and low season around Spring Festival (January, February, and March). Therefore, I include district Fixed Effects and month Fixed Effects in the models to control the time-invariant and spatial-invariant unobservables.

The empirical reveals that the affected distance of a BOWB is 0.7 km, and the remediation project does not affect housing values for properties further than 0.7 km. According to this finding, I divide the housing sample into treatment group (<0.7 km) and control group (0.7-3km). Based on unit housing prices, the BOWB remediation project increases 11.6% of housing prices for properties located within 0.7 km of a BOWB compared with properties situated between 0.7 and 3 km away from a BOWB. The listing effect causes 7% higher prices, and the completion effect causes 3.6% higher prices for the treatment group than the control group. Surprisingly, the listing effect is positive and more remarkable than the completion effect, suggesting that people will consider future value changes for housings transacted in the present. Regarding structural variables, I find that as total floor areas and number of bedrooms increase, the unit housing price decreases up to 0.9% and 1.7%, respectively. This may reveal that buyers in my dataset prefer small properties to large properties because small properties have relatively lower total prices, which is more affordable for buyers with a limited budget. Thus, they are more willing to purchase small properties with slightly higher unit prices but lower total prices. For locational characteristics, it is notable that the impact of the distance to the nearest subway is insignificant. One possible explanation is that because most of my samples are located in areas with dense subway stations and well-developed transportation systems, people do not value subway stations that much. Based on a back-of-envelop calculation, the benefit of BOWB remediation projects in Shanghai is 36 billion RMB.

This paper makes the following contribution to the existing literature. Firstly, it demonstrates the feasibility of Linden and Rockoff's Local Polynomial Regression method to detect the affected distance of severely polluted water bodies. Secondly, this study contributes to the growing literature on estimate environmental qualities using Hedonic Price models. As more and more Chinese cities start to account Gross Ecosystem Product, the remediation benefit valued by housing prices provides a simple accounting approach to quantify the monetary value of water quality improvement.

The rest of the paper is organized as follows. Chapter 2 briefly introduces background information of BOWBs, Shanghai City, and Shanghai housing policies. Chapter 3 reviews related literature. Chapter 4 describes the data. Chapter 5 discusses the empirical methodology I employ to identify the BOWB-affected distance and examine the impacts of BOWB remediation, listing, and completion. Chapter 6 presents empirical results. Chapter 7 concludes.

CHAPTER 2:

BACKGROUND

2.1 BOWBs in Shanghai

Shanghai is in the alluvial plain of the Yangtze Delta and coved by dense waterways. Its major water bodies include the Yangtze River, Huangpu River, Suzhou river, and Dingshan Lake. Among 16 districts, 14 districts have BOWBs except for Huangpu and Chongming. Lu et al. (2019) identify four main reasons causing BOWBs. Firstly, mixed and faulty sewage pipelines and rainwater pipeline systems cause untreated sewage to be directly discharged into natural water bodies. Secondly, large amounts of sewage water originally stored in the rainwater pump stations are discharged into rivers quickly before and during storming to prevent flooding. Thirdly, some regions and buildings lack infrastructure, so sewage water cannot be collected and treated. Last but not least, some small creeks lack sufficient water cycle. Wang et al. (2021) summarize the effects of BOWB on the city from three aspects. For residents, BOWBs negatively impact their mental and physical health while degraded environmental quality harm local economic development. For the city's ecological environment, the existence of BOWBs damages the city landscape as well ecosystem. Moreover, for city development, BOWBs ruin the city's image and reveal the incapability of city management.

In April 2015, the State Council of China launched the Action Plan for Water Pollution Prevention and Control, which provides a comprehensive water pollution prevention and control plan. The Action Plan requires cities to eliminate 90% BOWBs by 2020. In August 2015, the Ministry of Housing and Urban-Rural Development of China (MOHURD) issued the Work Guide for the Treatment of Black-odorous Water Bodies in Cities. The Work Guide provides clear guidelines and general rules for BOWB identification, plan design, technology selection, evaluation standards, and implementation.

7

As the Work Guide required, a BOWB is identified in two steps: firstly, the government should pre-evaluate and publish the BOWB pre-listing results; for disputed water bodies, the government should survey no fewer than 100 nearby residents, merchants, or random pedestrians. If more than 60% of the respondents deem the water body as "black" or "odorous," then the water body will be listed as a BOWB. Then, BOWBs are graded as either "mild" or "severe" according to transparency, dissolved oxygen (DO), oxidation reduction potential (OPR), and ammoniacal nitrogen (NH_3-N) levels. The severity level is served as a reference for the remediation plan and evaluation. The list of BOWBs includes names, locations, waterbody types, area/length, black and odorous severity levels, current conditions and expected completion dates, etc. Following the Work Guide, Shanghai listed 56 BOWBs in December 2015, and the spatial distribution is shown in Figure 1.

For completion evaluation, the Work Guide requires third-party organizations to evaluate the remediation effects based on continuous supervision of six months and publish the evaluation results to the public. The evaluation report should contain at least four parts: a public survey, a third-party monitoring report, image recording materials of implementation, and a long-term management plan. In terms of public surveys, the evaluation company collects at least 100 effective responses for each BOWB. If more than 90% of the respondents deem "satisfied" or "very satisfied," this water body remediation is recognized as completing. Besides that, qualified third-party monitoring organizations should monitor each water body with at least three testing points and continuously for six months.
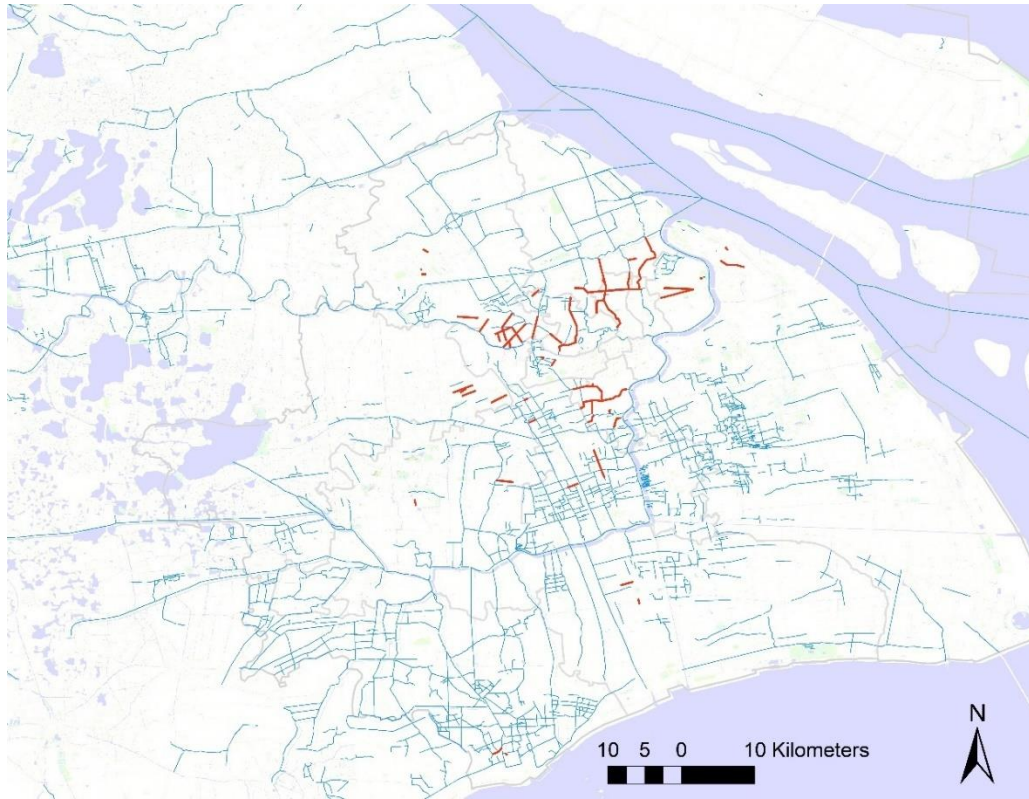
Figure 1: Spatial Distribution of BOWBs in Shanghai

Moreover, city governments should develop a mechanism to manage listed water bodies after completion and encourage the public to participate in BOWB long-term monitor. Public participation plays a decisive role in the BOWB listing and completion process. Thus, in this paper, I assume all buyers and sellers, after announcing listing and completion, are fully aware of the existence and condition of BOWB. This satisfies the underlying assumption of the Hedonic Model that buyers are fully informed (Bishop et al., 2020). Moreover, because the listing process majorly relies on public opinions, it avoids the issue of selection bias that local government would prioritize less-developed areas. Additionally, to restrain the difference between treatment and control groups, I restrict the whole housing sample to be within 3 km from a BOWB and delimit this large sample into treatment and control groups.

9

In 2017, all BOWBs in Shanghai achieved satisfaction rates of over 90%. In 2018, the state inspection team of BOWB remediation required the local government to resurvey at least 100 nearby residents for every BOWB, and all the BOWBs in Shanghai reached 90% satisfaction again. This ensures that no recurrence of BOWB happens in 2018.

In this paper, I regard 2015 as the pre-listing stage, 2016-2017 as the remediation stage, and the year 2018 as the completion stage. The overall timeline is shown in Figure 2.

Pre-listing Period Sample A	Remediation Period Sample B	Completion Period Sample C
2015.12.31 Announce BOWB list		2017.12.31 Announce completion of remediation for all BOWBs
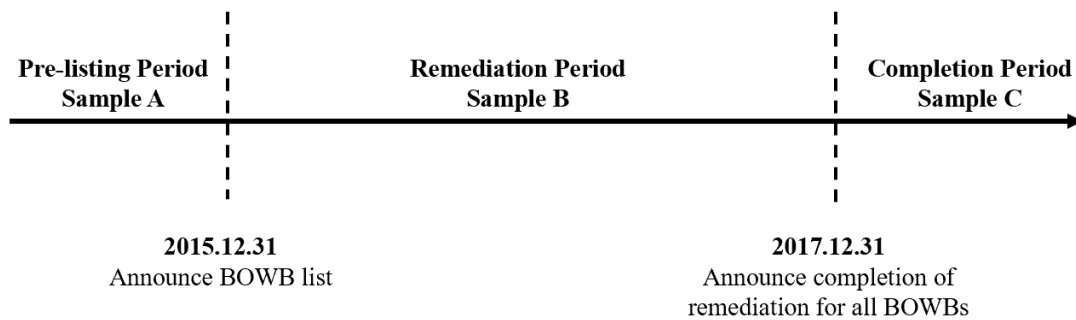
Figure 2: Timeline of BOWB Remediation Process

2.2 Shanghai City

Shanghai is one of the largest metropolitan areas in the world with over 24 million people and 6340 square kilometers. Its urbanization started in the 19th century, when it was developed as a port city trading with foreign countries (Zheng. 2005). From the 19th century to the early 20th century, the British, French, and United States set up concessions to the city's north and along the Huangpu River for international trading purposes. The urban development in this period was around the Concessions and along the Huangpu River. The Concessions attracted many upper-class people to settle due to its commercial standing. Since then, the Concessions areas have become a high-end place in Shanghai. After 1949, the foundation of New China, Shanghai was positioned as an industrial city and many industrial zones were developed in the suburban areas. Since the late 1980s, the reform and opening-up, Shanghai has been upgrading industries from production to finance. In 1992,

Shanghai established a special economic zone – Pudong District, in the city's southeast corner. With strong policy support, Pudong grows remarkably and is famous for its finance and high-tech industries. In the first decade of the 21st century, the concept of regional development was raised up. Shanghai, positioned as the leading city of the Yangtze River Delta city cluster, developed westwards to connect Zhejiang Province.

Because of the asynchronous urban development, the housing markets in different districts have various patterns. For example, in the former Concession areas like Huangpu and Jingan, although buildings are aged, people are still willing to pay more for its unique western-style environment. In regions with high-tech parks, like Pudong Zhangjiang High-tech Parks, people prefer to settle near the working places instead of the CBD. Overall, 16 districts can be divided into three categories:

1) *Central areas:* Huangpu, Jingan, Xuhui, Changning, Yangpu, Hongkou, and Putuo;
2) *New town* (half urban and half suburban area): Putong;
3) *Suburban areas*: Baoshan, Minhang, Songjiang, Jiading, Qingpu, Fengxian, Chongming, Jinshan (Zhang, 2018).

2.3 Housing Policies in Shanghai
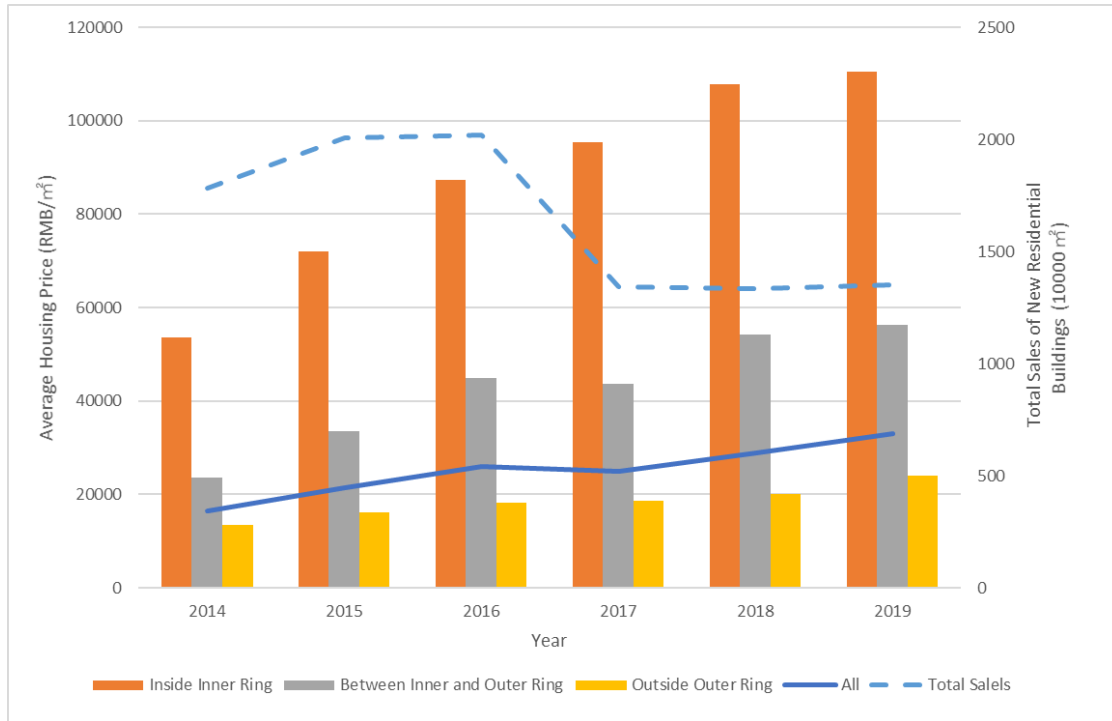
Figure 3: Housing Prices in Shanghai, 2014-2019

The Shanghai housing market experienced soaring prices and sales from 2015 to 2016 due to easy housing and mortgage policies for real estate destocking (Shanghai Municipal Bureau of Statistics, 2016) (Figure 3).

During the study period, four major types of housing price regulation policies were in effect: purchase restriction policy, loan restriction policy, price restriction policy, and sales restriction policy. In 2016, the Shanghai government modified its purchase restriction policies for non-local residents buying their first house in Shanghai. Previously, non-local buyers were required to pay income tax or social insurance in Shanghai for two consecutive years. Under the new policy, the required number of consecutive payment years increases to five. Moreover, following the national policies to regulate property markets, Shanghai tightened mortgage policies by raising interest rates and down payments, and strictly

controlling loan qualification (Urban Surveyors, 2020). These policy changes are aimed to prevent speculation, and I assume that they do not significantly affect normal buyers.

Moreover, Shanghai itself is a city with convenient transportation, and thus, the costs of moving within Shanghai are unlikely to be significant. Secondly, the citywide purchase restriction policies did not hinder moving and buyers' qualifications. Overall, I regard that the housing market of Shanghai satisfies the "law of one price function" assumption of Hedonic Model (Bishop et al., 2020).

CHAPTER 3:

LITERATURE REVIEW

3.1 Hedonic Price Model

The Hedonic Price Model is used to explain the price differentiation of housings. The model is firstly introduced to housing market research in the later 1970s and suggests that the price differentiation of housing is explained by housing attributes (Ball, 1973, Chau et al., 2001). The most often adopted housing characteristics include locational attributes (L), structural attributes (S), and neighborhood attributes (N). Locational attributes are usually in the form of proximity to important facilities, such as the distance to CBD and accessibility (Ridker & Henning, 1968). Structural attributes refer to physical characteristics of the property itself, such as built year, floor area, number of bedrooms, facing south or not, etc. The neighborhood attributes are more varied and reflect the social-economic classes of the neighborhood. Selected attributes vary from case to case. In China, the Hedonic Model is mainly applied to explain the housing market after the 2000s, before which the market did not exist and housing itself is untradable and is a welfare of the planning economy(Wang, 2006).

Within the context of Shanghai, Wang and Huang (2007) built a Hedonic Model using the distance to CBD, floor area, distance to the subway station, number of floors, interior design, river view, and green space as independent variables. They found that the view of Huangpu river increases housing prices by 33.96%, and the view of green space increases housing prices by 17.86%.

Moreover, researchers also improve the classic Hedonic Model to address spatial autocorrelation on housing, which is the spatial Hedonic Price Model. So far, there are generally three ways to tackle the spatial autocorrelation issue: 1) some researchers used dummy variables of the administrative zone like district, to capture spatial attributes; 2) Dubin (1988) artificially created 500-feet grids to capture spatial correlation; and 3) Can

(1992) applied a spatial lag model. In the context of environmental quality, spatial Hedonic Models have been widely used. Freeman (2003), Bayer (2006), and Anselin (2008) explored the applications of spatial Hedonic Price Model on air quality.

3.2 Valuation of Water Quality Using Hedonic Models

Researchers have long applied Hedonic Price Models to estimate the value of water quality from different aspects. Epp and Al-Ani (1979) found that pH level greatly affects housings near clean streams but has no effect on housings adjacent to polluted streams in Pennsylvania. Boyle et al.(1998), Michael et al. (1996), and Gibbs et al. (2016) studied the impact of water clarity on housing prices. They found that water clarity has significant impacts on lakefront property values. More explicitly, Poor, Pessagno, and Paul (2007) found that total suspended solids and dissolved inorganic nitrogen negatively affect housing values. Muehlenbachs et al. (2015) studied the groundwater contamination risk from shale gas development using triple-difference models. They found that shale gas development has a significant negative impact on nearby groundwater-dependent homes.

In terms of the Hedonic applications in China, there is little on valuing water quality. Chen (2016) studied the impact of water pollution and river restoration in Guangzhou, China, and found that river restoration can reverse the negative effect of water pollution. Wen (2005) included the distance to West Lake as an aesthetic element in the Hedonic Model of Hangzhou. Wang and Huang (2007) included view of Huangpu River (dummy), view of Suzhou River (dummy), distance to Huangpu River, distance to Suzhou River, view of garden (dummy), and distance to park in the model of Shanghai. After inspecting multicollinearity, they found that only the view of Huangpu river and the view of garden are effective. These studies either use proximity to waterbody or dummy variables of viewing as measures of accessibility to water bodies. Minor studies examine the affected distance of polluted rivers and policy impacts of river remediation.

In this paper, I borrow the idea from Linden and Rockoff (2008), who used Local Polynomial Regressions to detect the affected distance of sex offenders and applied DID models to estimate sex offenders' impacts on housing values before and after arrives. They hypothesized that if a sex offender has a negative impact on housing values, we should observe a more significant impact on homes closer to the offender. They drew the price gradients of distance to sex offenders' locations before and after offenders' arrives and found a sharp decrease in housing prices for housing within 0.1 miles of the offenders' locations. Then, they employed DID Hedonic Models to housings within 0.1 miles and within 0.1 and 0.3 miles before and after sex offenders' arrives. The same strategy was adopted to study the impact of shale gas development, the impact of brownfield remediation, and the impact of new mass rapid transit lines (Haninger et al., 2014; Muehlenbachs et al., 2015; Diao, Leonard, and Sing, 2017).

CHAPTER 4:

DATA

4.1 BOWB

BOWB listing data were collected from GeoHey.com, including name, location, length, severity, and expected completion dates, originally obtained from the national BOWBs list. In December 2015, the Shanghai government reported 56 BOWBs, including 46 mild-level rivers BOWBs and ten severe-level BOWBs, with a total length of 130 kilometers. The spatial distribution of BOWBs is shown in Figure 2.1.

The Shanghai Action Plan (2015) clearly set up the timeline and goals of the BOWBs remediation actions. Based on this, I divided the whole process into three periods:

1) *Listing (Dec 30, 2015)*: investigated BOWBs by surveying residents and experts
2) *Remediation (2016-2017)*: remediated BOWBs
3) *Completion (Dec 30, 2017)*: surveyed satisfaction rate of nearby residents and considered as complete if the rate is over 90. Based on the latest first survey time, all the remediations were completed in December 2017.

4.2 Housing Transaction Data

The individual housing transaction data were web-scraped from Lianjia.com, the largest real estate brokerage company in mainland China in October 2020. Lianjia.com posts individual housing transaction records, including housing prices and housing-related attributes, such as the number of bedrooms, floor levels, built year, floor area, equipped with elevator or not, and so on. Because of privacy protection, they do not provide street and number information. Due to the lack of exact addresses, the individual housing data are aggregated and geocoded to the Xiaoqu level (community in Chinese).

The original dataset includes 237,512 transaction records from 2011 to 2020. For this paper, I only keep transactions between 2015 and 2018, whose property type is commercial residential building, and whose property use is residence. Missing data in structural

17

characteristics and housing prices are deleted, including listed total price, floor level, building type, year built, elevator, number of bedrooms. Outliers are detected in two steps. Firstly, I calculate the absolute difference in percentage between unit housing prices and average unit prices of Xiaoqu, and between transaction prices and listed prices. If both differences in percentage are greater than 100%, these transactions are regarded as outliers and deleted. Secondly, for differences in percentage are between 60-99%, I compared the unit prices with the unit prices of similar properties in the same Xiaoqu and the same transaction year. Transactions with large differences were deleted.

Then, I restrict the data to properties within 3 km to only one BOWB. Properties within 3km to more than one BOWB are eliminated due to consideration of multiplicative impacts of BOWBs. After data cleaning, the entire dataset has 4961 observations in Sample A (transacted in 2015), 10244 in Sample B (transacted in 2016 and 2017), and 3501 in Sample C (transacted in 2018). Figure 4 shows the time-series trend of monthly average housing prices during the study period, and Figures 5 - 7 show the spatial distribution of selected housing transactions in each sample. As mentioned, 2016 is a special year experiencing soaring housing prices. It is also believed that spatial factors such as district and Jiedao (subdistrict in Chinese) impact housing prices. To capture these unobserved spatial and temporal factors, I generated district and monthly dummies.
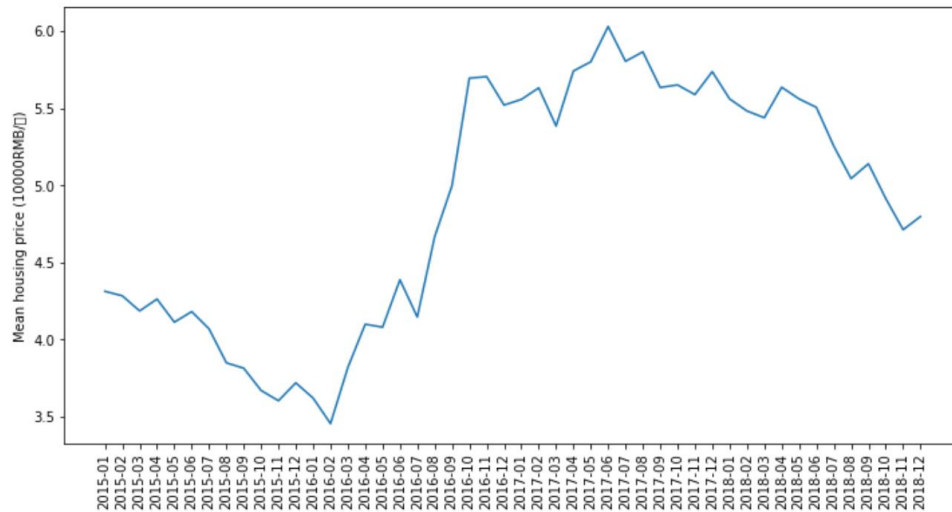
Figure 4: Monthly Averaged Housing Prices from 2015.01 to 2018.12
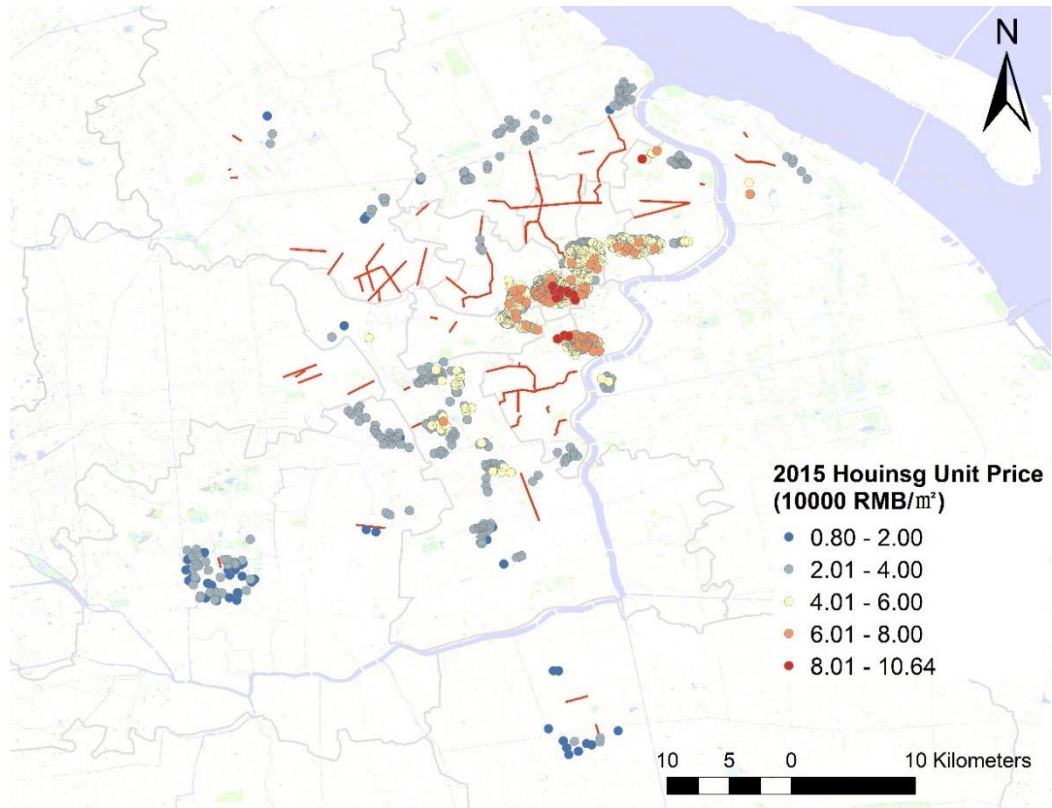
Figure 5: Spatial Distribution of Housing Transactions, Sample A: 2015
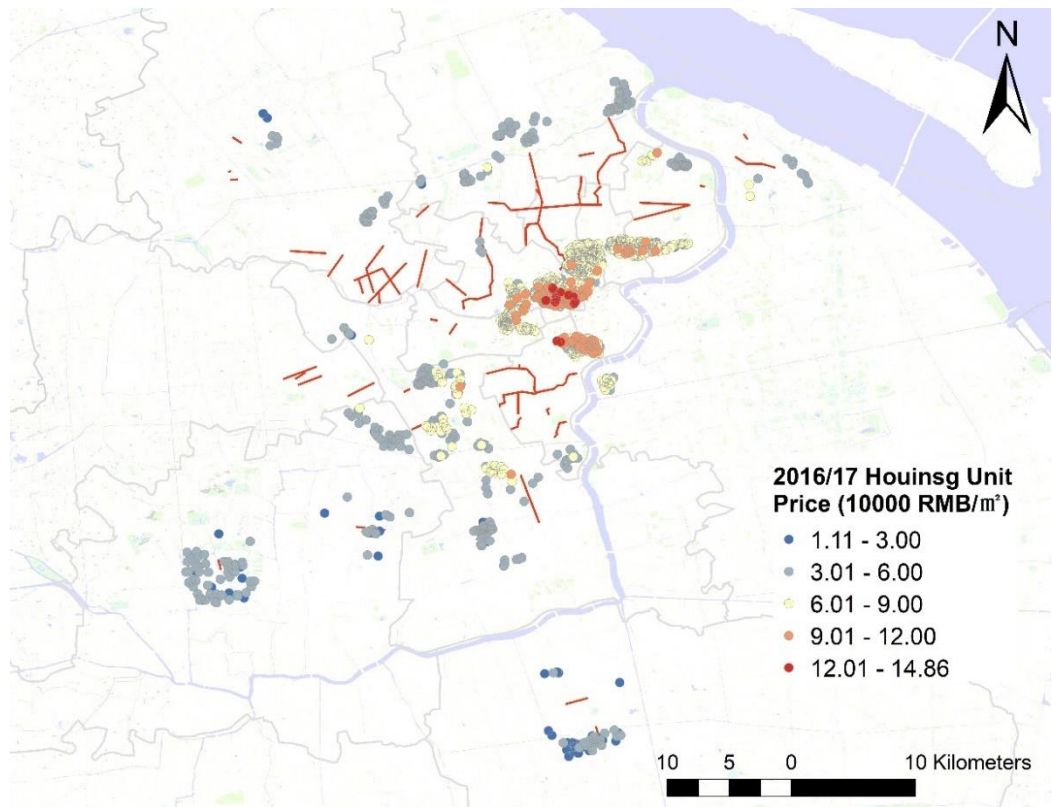
Figure 6: Spatial Distribution of Housing Transactions, Sample B: 2016 and 2017
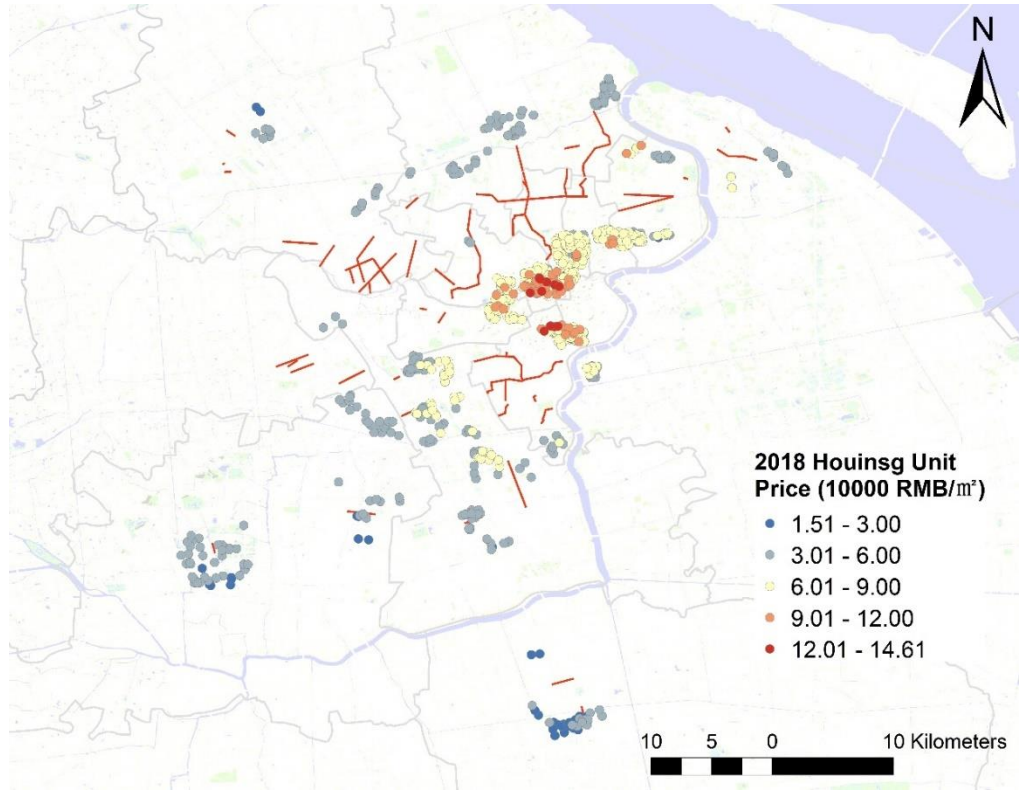
Figure 7: Spatial Distribution of Housing Transactions, Sample C: 2018

4.3 Locational Variables

In the study, I use six locational variables to control their impacts on housing prices, including distance to the nearest subway stations, distance to the nearest school, quality of the nearest school, distance to the nearest park, the star level of the nearest park, and distance to the CBD.

Subway stations data are collected from Shanghai Metro official website (http://www.shmetro.com/) and related subway planning documents. The data are separated into three samples according to their operation time:

1) *Sample A (Listing)*: all subway stations opened in 2015, 333 stations in total;
2) *Sample B (remediation)*: all subway stations opened in 2016 and 2017,345 stations in total; and
3) *Sample C (completion):* all subway stations opened in 2018, 380 stations in total.

20

Distance to the nearest subway stations is calculated using ArcGIS Near function.
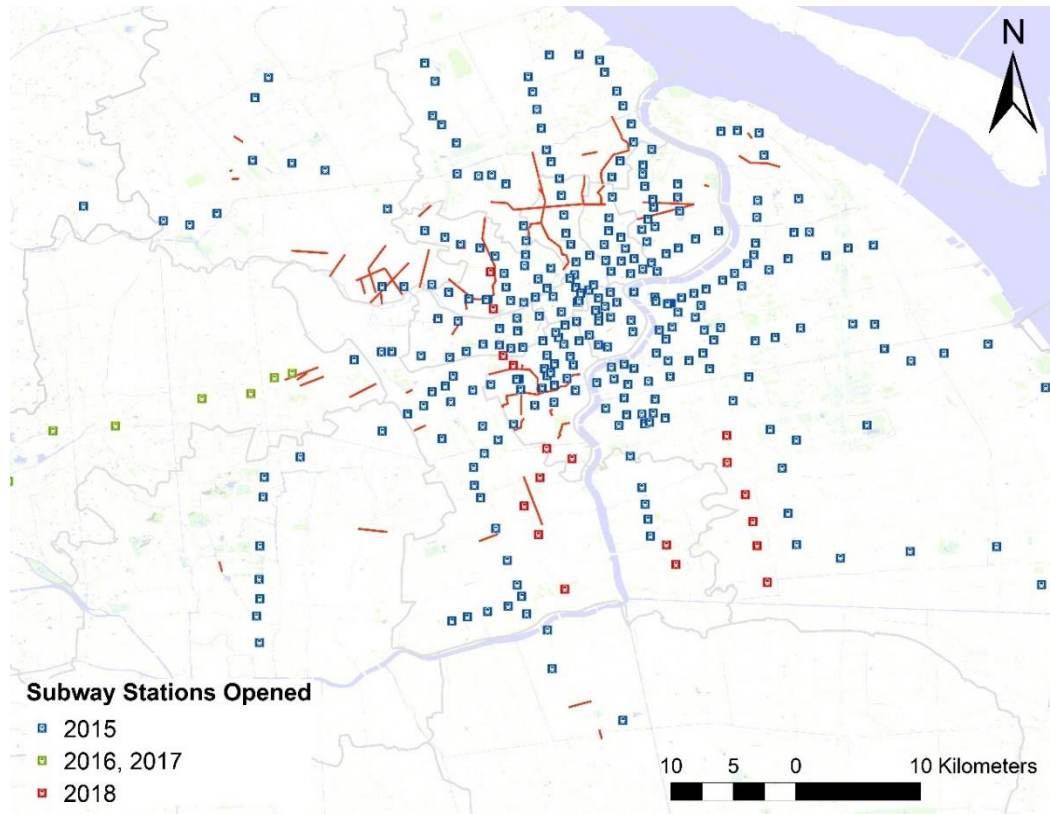
Figure 8: Spatial Distribution of Subway Stations Opened in Year 2015, 2016&2017, and 2018

School data are collected from kaowang.com, a website providing a ranking of schools. Considering that elementary and middle schools students majorly come from their school districts while high schools can admit students citywide and provide accommodation, I only include elementary and middle schools in my dataset and assign school quality 1 to 3 based on their tiers ranked by kaowang.com. Schools in tier 1 are the best and assigned 3 to their school quality. Distance to the nearest school is measured using ArcGIS Near function.
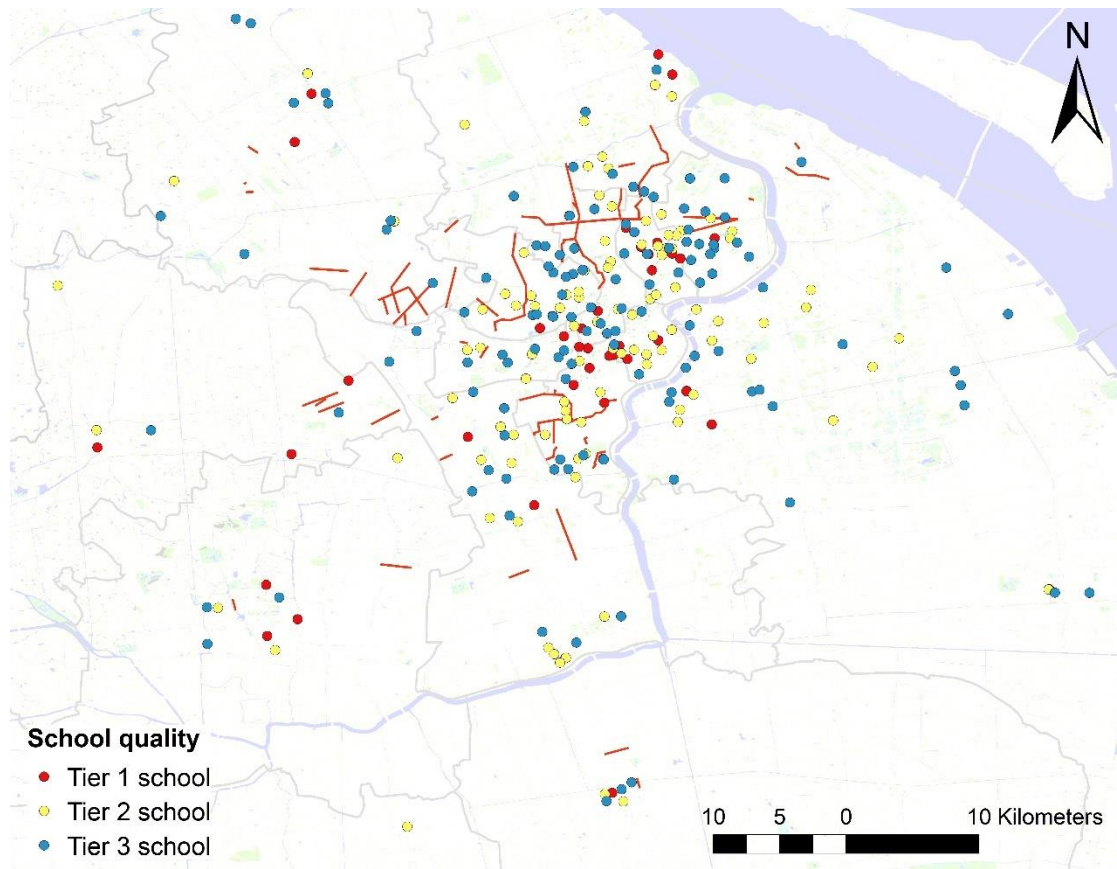
Figure 9: Spatial Distribution of Elementary and Middle Schools in Shanghai with School Quality

Notes: Schools in tier 1 have the best quality.

Star-rated park lists are provided by Shanghai Landscaping and City Appearance Administrative Bureau. The Bureau has reviewed and released a list of star-rated parks every two years since 2009. The rating standard covers planning, archives management, landscaping management, environmental health, equipment maintenance, operation, and security management. For parks larger than 70,000 m^2, the star level is rated from three to five. For parks smaller than 70,000 m^2, the star level is rated from two to three. Distance to the nearest park is measured using ArcGIS Near function.
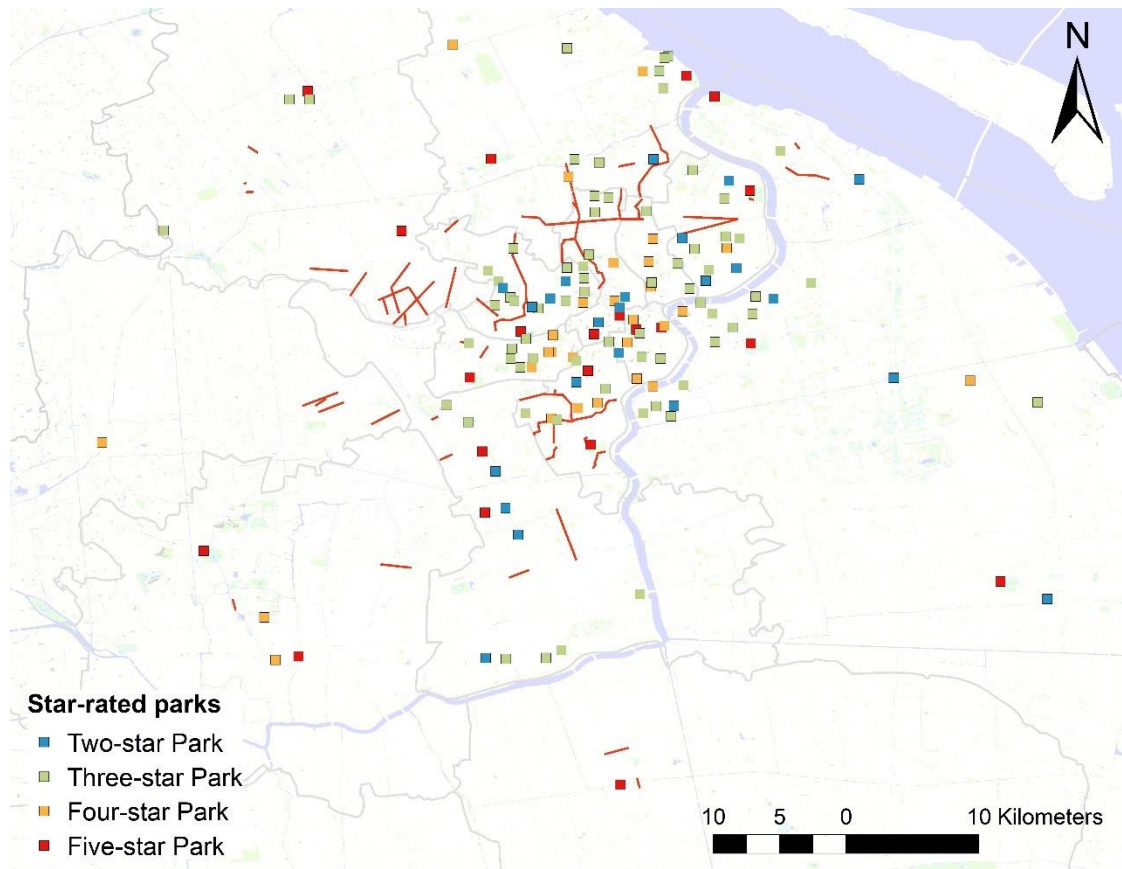
Figure 10: Spatial Distribution of Star-Rated Parks in Shanghai with Park Star Level

Based on current housing prices distribution and Shanghai planning, I regard
Shanghai as a monocentric city and select the CBD location according to *SHANGHAI
MASTER PLAN 2017-2035*. Distance to the CBD is measured using ArcGIS Near function.

The summary statistics of all variables are shown in Table 1.

Table 1: Summary Statistics

Variables	Description	Pre-listing (2015)		Remediation (2016-2017)		Completion (2018)	
		mean	std	mean	std	mean	std
BOWB							
Distant to BOWB	distance to the nearest BOWB (km)	2.10	0.65	2.06	0.72	2.08	0.71
Severity	severity of the nearest BOWB, 1 if severe, 0 if mild	0.35	0.48	0.34	0.48	0.34	0.47
Dependent Variable							
Ln(unit price)	natural logarithm of housing unit price in RMB per square meter	10.49	0.39	10.67	0.46	10.79	0.39
Structural Characteristics of Housing							
Built year	built year of buildings	2001	7.94	1999	9.93	1998	10.33
Floor area	floor area of the property, in square meter	98.34	40.44	83.28	38.60	78.35	35.39
Unit price	unit price of the property, in 10000 RMB per square meter	3.87	1.49	4.73	2.07	5.26	2.09
# bedrooms	number of bedrooms	2.11	0.94	1.99	0.87	2.01	0.78
# bathrooms	number of bathrooms	1.29	0.60	1.20	0.50	1.18	0.42
Facing south	1 if facing south, 0 if not	0.83	0.38	0.79	0.41	0.94	0.24
Floor level	floor level of the property, 3 if on upper floor, 2 if on middle floor, 1 if on lower floor, 0 if on ground floor	2.04	0.80	2.08	0.79	2.08	0.78
Having elevator	1 if having elevator, 0 if not	0.67	0.47	0.46	0.50	0.41	0.49
Locational Characteristics of Housings							
Distance to subway	distance to nearest subway station(km)	1.15	1.19	1.59	1.65	1.60	1.80
Distance to school	distance to nearest school(km)	1.03	0.99	1.29	1.35	1.39	1.57
School quality	school quality, 3 if in the first tier(best), 2 if in the second tier, 1 if in the third tier.	1.85	0.82	1.76	0.77	1.84	0.80
Distance to park	distance to nearest park(km)	1.54	1.36	1.90	1.65	1.96	1.76
Park star	nearest park star level, 5 levels in total, 5 indicates the best quality	3.42	1.05	3.49	1.07	3.43	1.08
Distance to CBD	distance to CBD (km)	11.15	8.89	14.92	10.51	14.60	9.88

Table 2: Summary Statistics by Treatment and Control Groups

| Variables | Pre-listing (2015) | | | | Remediation (2016-2017) | | | |
| | Treatment | | Control | | Treatment | | Control | |
	mean	std	mean	std	mean	std	mean	std
BOWB								
Distant to BOWB	0.52	0.16	2.18	0.56	0.44	0.19	2.19	0.58
Severity	0.50	0.50	0.34	0.47	0.52	0.50	0.33	0.47
Dependent Variable								
Ln(unit price)	10.24	0.36	10.50	0.39	10.43	0.39	10.68	0.46
Structural Characteristics of Housing								
Built year	2004	6	2001	8	2003	7	1999	10
Floor area	94.26	32.99	98.55	40.77	88.42	36.91	82.86	38.71
Unit price	3.01	1.15	3.91	1.49	3.66	1.56	4.82	2.08
# bedrooms	2.01	0.92	2.12	0.94	2.08	0.91	1.98	0.86
# bathrooms	1.22	0.54	1.30	0.60	1.24	0.54	1.20	0.50
Facing south	0.84	0.37	0.83	0.38	0.78	0.42	0.79	0.41
Floor level	1.96	0.78	2.04	0.80	2.05	0.79	2.08	0.79
Having elevator	0.59	0.49	0.67	0.47	0.52	0.50	0.45	0.50
Locational Characteristics of Housing								
Distance to subway	1.23	1.13	1.15	1.19	2.66	2.90	1.50	1.47
Distance to school	2.20	1.56	0.97	0.91	3.40	2.52	1.12	1.03
School quality	1.77	0.60	1.85	0.83	1.84	0.56	1.75	0.78
Distance to park	2.08	1.10	1.51	1.36	3.27	2.37	1.79	1.52
Park star	3.13	1.04	3.43	1.04	3.48	1.26	3.49	1.05
Distance to CBD	15.94	10.09	10.90	8.76	19.54	9.08	14.54	10.53
# of obs	239		4722		765		9479	

Notes: Treatment group includes housing properties within 0.7km of the nearest BOWB, and the control group includes housing properties within 0.7 - 3 km of the nearest BOWB

Table 2 (Continued) Summary statistics by treatment and control groups

Variables	Completion (2018)			
	Treatment		Control	
	mean	std	mean	std
BOWB				
Distant to BOWB	0.45	0.19	2.19	0.58
Severity	0.61	0.49	0.32	0.47
Dependent Variable				
Ln(unit price)	10.52	0.32	10.81	0.39
Structural Characteristics of Housing				
Built year	2003	8	1998	10
Floor area	79.73	28.33	78.26	35.84
Unit price	3.91	1.49	5.35	2.09
# bedrooms	2.03	0.74	2.01	0.79
# bathrooms	1.18	0.41	1.18	0.42
Facing south	0.94	0.25	0.94	0.24
Floor level	2.00	0.79	2.09	0.78
Having elevator	0.55	0.50	0.40	0.49
Locational Characteristics of Housing				
Distance to subway	3.46	3.35	1.47	1.55
Distance to school	3.90	2.88	1.21	1.26
School quality	1.87	0.58	1.84	0.81
Distance to park	3.93	2.72	1.82	1.58
Park star	3.85	1.25	3.40	1.06
Distance to CBD	20.90	8.75	14.16	9.81
# of obs	233		3273	

Notes: Treatment group includes housing properties within 0.7km of the nearest BOWB and the control group includes housing properties within 0.7 - 3 km of the nearest BOWB.

CHAPTER 5:

EMPIRICAL METHODOLOGY

I embed a Difference-in-Difference model ("DID") in the Hedonic price framework to measure the housing price change due to BOWB remediation. The first task of building a DID model is to identify its control and treatment groups. I follow the same strategy that Linden and Rockoff (2008), Muehlenbachs et al. (2015), Diao, Leonard, and Sing (2017) employ to detect the distance where a localized amenity no longer has impacts. Housings that are within the distance are defined as the treatment group affected by the remediation, while housings that are beyond the threshold distance but within 3 km are considered as the control group, which have similar characteristics as the treatment group but are not affected by the remediation.

The whole BOWB remediation process is divided into three phases by two events: announcement of listing and completion. To measure the impact of remediation, I run a DID Hedonic regression for housing transactions that happened before listing (Sample A) and after completion (Sample C). Its results reflect the overall impact of remediation. Considering that housing is a durable good, people will count for its futural value. While listing, the BOWB nearby housings were expected to be better off in the future, so I assume that the listing event will positively impact housing prices.

Similarly, the announcement of completion is also assumed to have a positive impact on housing prices. Its impact comes from the environmental improvement impact of the BOWB remediation project and people's belief of future benefits. To measure the single impact of listing and completion separately, I employ two DID Hedonic Models for housing transactions happened before listing (Sample A) and transactions after listing but before completion (Sample B), and for housing transactions happened after listing but before completion (Sample B) and transactions after completion (Sample C).

27

5.1 Identification of BOWB-Affected Distance

It is assumed that the impact of a BOWB on nearby residences is decreasing as distance increases, and at a certain point, its impact will be close to zero. Linden and Rockoff (2008) innovatively adopt a Local Polynomial Regression to detect the point where the effect of a localized amenity vanishes. Here, I apply the same strategy to detect the distance threshold of BOWB by running two Hedonic Models regressing housing prices on distances to BOWB before remediation (Sample A) and after remediation (Sample C) separately. The threshold distance is where the difference of price gradients of distance from BOWB is insignificant.

$$lnP_{it} = \beta X_{it} + \gamma_j + \delta_t + \varepsilon_{it} \tag{1}$$

where

lnP_{it} is the natural logarithm of housing i's unit price;

the vector X_{it} includes property i's structural and locational characteristics;

γ_j and δ_t are district Fixed Effects and month Fixed Effects, capturing spatial and temporal unobservables.

The Difference-in-Difference method requires treatment and control groups are as similar as possible to mitigate omitted variables. Thus, the BOWB-affected housing, as the treatment group, should have similar characteristics as the control group. According to Tobler's first law of geography, that near things are more related than distant things, the distance between treatment and control group should not be very large. Juang et al.(2010) find that VOC evaporating from a heavily polluted river can increase the risk of certain chronic diseases in residents living within 225 meters from the river. Based on this finding, I prepare two samples of 2015 (Sample A) and 2018 (Sample C) respectively and manually restrict samples only containing housing observations within 3 km to a BOWB to maintain a sufficient sample size. It is assumed that the affected threshold is where the difference of

residuals between the two samples is insignificant, indicating that the remediation no longer affects housing prices at this point.

5.2 Difference-in-Difference Model of Remediation Effect

The impact of remediation is the change of housing price between before listing and after completion, which includes the effect of listing and the effect of completion. It is an efficient way to measure the overall impact of the BOWB remediation policy. The equation is shown below:

$$lnP_{it} = \beta_1 X_{it} + \tau_1 remediation_{it} \cdot treatment_i + \beta_3 treatment_i + \gamma_j + \delta_t + \varepsilon_{it}$$

(2)

where

lnP_{it} is natural logarithm of unit housing prices;

X_{it} is a vector of housing attributes, including structural and locational characteristics;

$remediation_t$ is a dummy variable of remediation condition, equal to one if the property i is transacted after completion, and 0 otherwise;

$treatment_i$ is a dummy variable that it is equal to 1, if the property i is located within 0.7 km from a BOWB, and 0 otherwise;

γ_j is location fixed-effects in district level;

δ_t is month of sample fixed-effects; and

ε_{it} is error term.

τ_1 is the coefficient of interest and is expected to be positive, suggesting that the BOWB remediation can increase the housing prices of properties located within 0.7 km from a BOWB compared with housing prices of properties unaffected by BOWB.

5.3 Difference-in-Difference Model of Listing Effect

The impact of listing is always hard to determine because it can affect buyers from different channels. Firstly, subjective beliefs of homebuyers might not be consistent with the objective condition. If the buyers are not fully informed, their decision cannot accurately reflect their values on amenity level. Because of the listing survey process and disclosure of listing, it is assumed that buyers are fully informed after the listing, and thus buyers' perception of the housing values should be adjusted and more accurately reflect their preferences (Boyd et al., 2015; Bishop et al., 2011). Second, since housing is a durable good, homebuyers always consider the evolution of amenities in the future. A listed BOWB indicates that it will be treated and improved within two years, just like the planning of subway stations which always raise nearby housing prices. Similarly, homebuyers may expect the amenity will be enhanced and adjust their values. I apply a Difference-in-Difference model to measure the impact of listing.

$$lnP_{it} = \beta_1 X_{it} + \tau_2 listing_t \cdot treatment_i + \beta_3 treatment_i + \gamma_j + \delta_t + \varepsilon_{it} \quad (3)$$

where

$listing_t$ is a dummy variable that equals to 1 if the housing property i is transacted after listing and before completion (Sample B), and equals to 0 otherwise.

τ_2 measures the change in housing prices within 0.7 km of BOWB due to listing. The post-listing sample only contains housing transactions that happened after listing and before completion to separate the effect of listing.

5.3 Difference-in-Difference Model of Completion Effect

Similar to the listing model, I apply a difference-in-difference method to quantify the completion impact of BOWB remediation on housing values.

$$lnP_{it} = \beta_1 X_{it} + \tau_3 completion_t \cdot treatment_i + \beta_3 treatment_i + \gamma_j + \delta_t + \varepsilon_{it} \quad (4)$$

where

$completion_t$ is a dummy variable of remediation condition, equal to one if the property i is transacted after completion (Sample C), and 0 otherwise.

τ_3 measures the changes in housing prices affected by completion of BOWB remediation, which is expected to be positive, implying the completion would benefit nearby housings.

5.4 Robustness Check: Unified Difference-in-Difference Model

Although three Difference-in-Difference models provide evidence for effects in different stages, I apply a unified Difference-in-Difference Model for the whole process to examine the robustness of estimates in previous models.

$$lnP_{it} = \beta_1 X_{it} + \tau_4 listing_t \cdot treatment_i + \tau_5 remediation_t \cdot treatment_i + \beta_3 treatment_i + \gamma_j + \delta_t + \varepsilon_{it} \tag{5}$$

where

$listing_t$ is a dummy variable that equal to one if the property i is transacted during the remediation period (Sample B), and 0 otherwise.

$remediation_t$ is a dummy variable of remediation condition, equal to one if the property i is transacted after completion (Sample C), and 0 otherwise.

β_3 indicates the baseline condition of BOWB nearby housing prices before any intervention, which is expected to be negative.

τ_4 is the listing effect. It measures the housing price changes before and after the listing.

τ_5 is the overall remediation effect, which captures the housing price change before listing (Sample A) and after completion (Sample C).

Thus, $\tau_5 - \tau_4$ is the completion effect, which quantified the housing price change due to announcement of completion.

31

EMPIRICAL RESULTS

6.1 Identification of BOWB-Affected Distance

To determine the affected distance of a BOWB, I regress log housing prices on the distance to the nearest BOWB, controlling all other factors (Equation (1)) for Sample A and Sample C, respectively, and apply a non-linear Local Polynomial Regression on the residuals from equation (1). If a BOWB has a negative impact on nearby housing prices, then it is expected to see lower prices of properties closer to the BOWB than properties further away. After remediation, the negative impact of BOWB should be eliminated. Thus, in terms of price gradients of distance from BOWB, we expect to see a sharp decrease for the line before remediation within a certain distance.

Figure 11 shows a sharp increase in housing prices within 0.7 km from a BOWB after remediation while the housing prices further than 0.7 km remain the same before and after remediation. The result suggests that 0.7 km is the threshold distance of BOWB impact.Therefore, properties within 0.7 km from a BOWB are regarded as the treatment group and properties within 0.7-3 km are set as the control group.
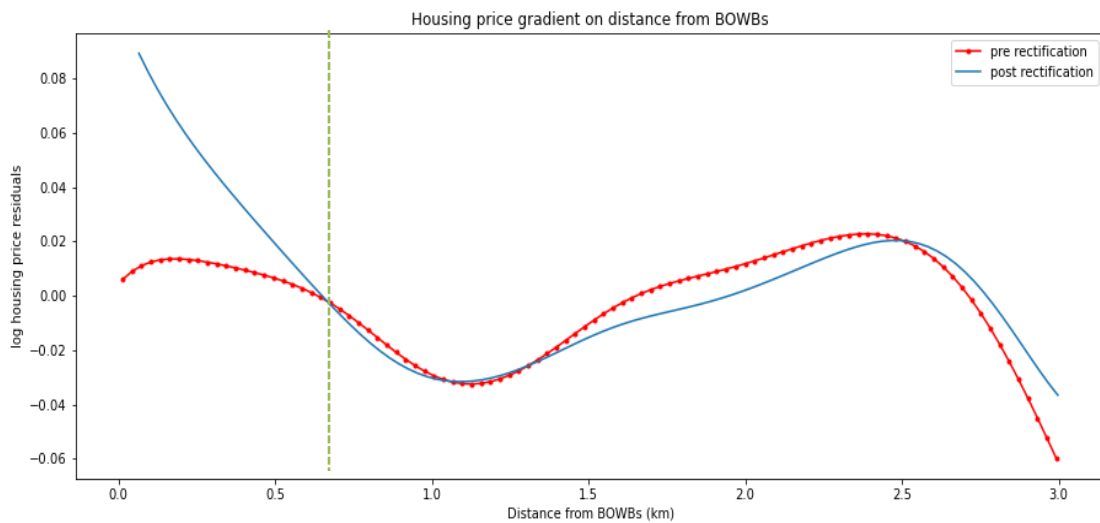
Figure 11: Housing price gradient on distance from BOWBs, bandwidth=0.489 km

6.2 Parallel Trend Assumption

The parallel trend assumption is the most important assumption of DID models. It requires treatment and control group have parallel trends overtime before the treatment happens. Violation of parallel trend assumption will cause a biased measure of causal effect. To verify this assumption, I firstly plot out the monthly averaged housing price over time for the treatment and control group in Figure 12. Then, I apply two event study models regressing log housing prices on month dummies for treatment and control groups, respectively, controlling all structural and locational factors and including district Fixed Effects and month Fixed Effects. Figure 13 shows the coefficients of BOWB treatment over time. The trends of control and treatment groups are almost parallel in both figures, validating the DID parallel trend assumption. Figure 13 also suggests that before listing, BOWB has a constantly negative impact on housing prices. The listing announcement and remediation process greatly reduce the negative effects to zero. After the announcement of completion, the impact of BOWB gradually drops below zero.
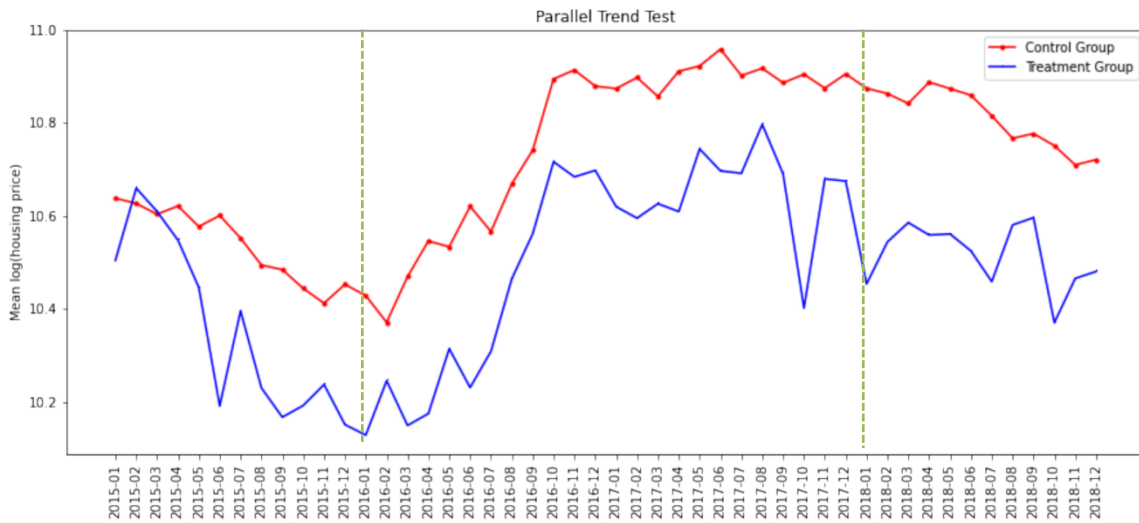
Figure 12: Monthly Averaged Housing Price for Treatment and Control Groups
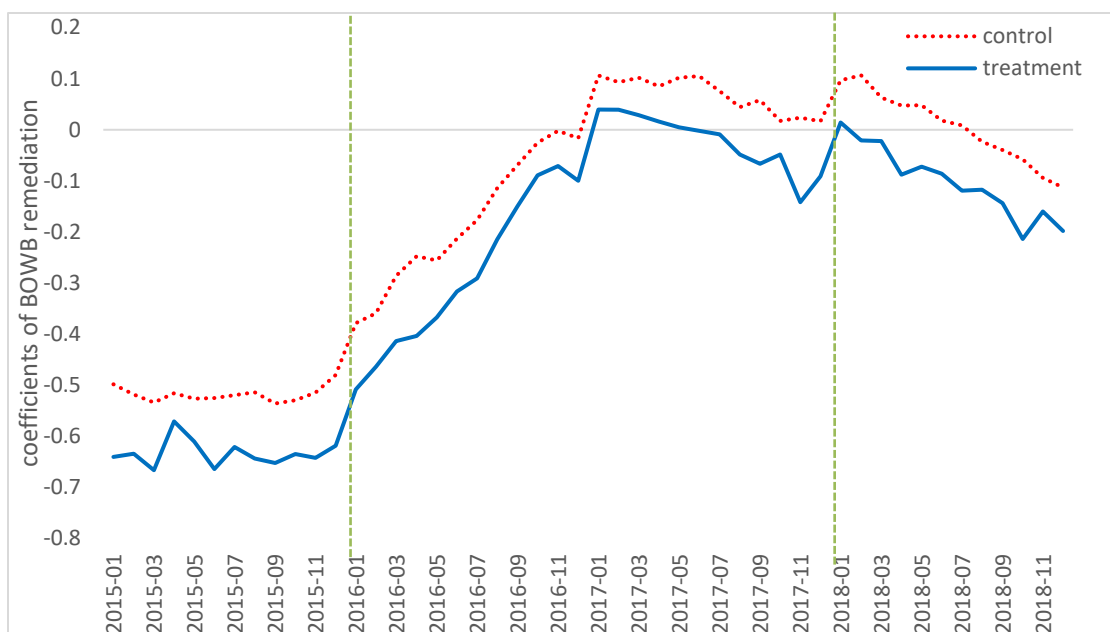
Figure 13: Impacts of BOWB Remediation on Housing Prices over Time for Treatment and Control Groups

6.3 Remediation Effect

Table 3 shows the estimated effects of BOWB remediation on housing prices using Sample A (pre-listing) and Sample C (after completion). The OLS result implies that the remediation can lead to an average 49.8% increase in prices for properties located within 0.7 km from a BOWB, compared with properties located within 0.7-3 km from a BOWB. After controlling time-invariant and spatial-invariant unobservables, the impact of remediation on nearby housing prices is 11.6%. It is obvious that BOWB remediation project has a substantially positive effect on housing prices.

6.4 Listing Effect

The results of listing DID model are reported in Table 4. The Fixed Effect model estimates that the announcement of listing results in 7% higher housing prices of BOWB nearby properties than properties more than 0.7 km away from a BOWB. The positive listing effect reflects that the belief of future environmental improvement outweighs the disclosure of the

current BOWB condition. Nearby residents and buyers expect that the listing and remediation plan will enhance neighborhood environment and also expect an increase in nearby housing prices.

6.5 Completion Effect

Table 5 displays the results of completion DID models. The FE estimated result is larger and significant, suggesting that announcement of completion results in 3.2% higher in BOWB nearby housing prices than prices of housings located between 0.7 and 3 km from a BOWB.

6.6 Robustness Check

Table 6 presents the results of unified DID model, which restricts the fixed effects to be the same across all samples and measures the average impacts of control variables such as distance to the subway station and floor areas. The coefficient of listing*treatment term represents the listing effect, which is 6.8%, really close to 7% shown in Table 5. The coefficient of remediation*treatment captures the overall remediation impact, which is 10.4% estimated using the unified model. The completion effect is the difference between remediation effect and listing effect, which is 3.6%. Overall, the estimates of listing, remediation and completion using the unified model do not significantly differ from previous results. In conclusion, the robustness check provide evidence that my estimates are reliable.

Notable, the listing impact is double the impact of completion. It can be concluded that the listing impact accounts for a greater part of overall remediation effect, implying that in the housing market, people take long-term changes into account and current transaction prices already include people's anticipation of future housing values. Another explanation is that the housing market reacts to the remediation policy and adjusts housing prices during the remediation process, 2015 to 2017. Moreover, the completion of the remediation project is not simultaneous. For example, as the government disclosures, Chunshengang finished its remediation and achieved a 99% satisfaction rate in September 2016. The announcement

time, December 2017, is the time for all BOWBs remediation finished. Therefore, it is very likely that the completion impacts of early completed projects have faded out.

For housing structural characteristics, it is surprising that number of bedrooms and floor areas have negative signs, indicating that as areas and bedrooms increase, the unit housing price decreases. One possible explanation is that Shanghai people favor small properties. The housing prices of Shanghai are really high and larger apartments are unaffordable for many buyers. Therefore, they prefer small properties because the total costs of small properties are more feasible. This leads to higher unit prices for small properties. Other variables like elevator, facing south, and built years, have expected positive signs, suggesting they positively impact unit housing prices.

In terms of neighborhood variables, all have expected signs except distance to the nearest subway station, which is insignificant. It is possible for this study because as shown in Figure 4, housings are located in subway-dense areas; thus, the distance to the subway station is not a key factor of housing prices.

Table 3: Remediation Effect

	OLS	FE
	ln(price)	ln(price)
remediation*treatment	0.498***	0.116***
	(0.027)	(0.017)
treatment	-0.239***	-0.083***
	(0.020)	(0.012)
constant	-7.103***	-10.210***
	(1.037)	(0.577)
Floor area	-0.002***	-0.001***
	(0.000)	(0.000)
# bedrooms	-0.005	-0.021***
	(0.006)	(0.004)
# bathrooms	0.072***	0.059***
	(0.009)	(0.005)
Floor level	-0.007*	-0.007***
	(0.004)	(0.002)
Having elevator	0.069***	0.098***
	(0.009)	(0.005)
Facing south	0.132***	0.038***
	(0.010)	(0.006)
Built year	0.009***	0.011***
	(0.001)	(0.000)
Distance to subway	0.008**	-0.001
	(0.004)	(0.002)
Distance to school	-0.042***	-0.054***
	(0.004)	(0.003)
School quality	0.041***	0.043***
	(0.004)	(0.003)
Distance to park	-0.040***	-0.027***
	(0.003)	(0.002)
Park star	-0.001	0.023***
	(0.003)	(0.002)
Distance to CBD	-0.027***	-0.019***
	(0.001)	(0.001)
District Fixed Effects	No	Yes
Month Fixed Effects	No	Yes
N	8467	8467
R2_Adj	0.535	0.832

Standard errors in parentheses.
* p<.1 ** p<.05 ***p<.01

Table 4: Listing Effect

	OLS ln(price)	FE ln(price)
listing*treatment	0.371***	0.070***
	(0.022)	(0.014)
treatment	-0.265***	-0.073***
	(0.019)	(0.013)
constant	-9.127***	-8.875***
	(0.743)	(0.438)
Floor area	-0.002***	-0.001***
	(0.000)	(0.000)
# bedrooms	-0.008*	-0.020***
	(0.004)	(0.003)
# bathrooms	0.104***	0.055***
	(0.007)	(0.004)
Floor level	-0.014***	-0.009***
	(0.003)	(0.002)
Having elevator	0.085***	0.087***
	(0.006)	(0.004)
Facing south	0.016***	0.030***
	(0.006)	(0.004)
Built year	0.010***	0.010***
	(0.000)	(0.000)
Distance to subway	0.015***	0.001
	(0.003)	(0.002)
Distance to school	-0.048***	-0.055***
	(0.003)	(0.002)
School quality	0.035***	0.042***
	(0.003)	(0.002)
Distance to park	-0.040***	-0.025***
	(0.002)	(0.002)
Park star	0.005*	0.022***
	(0.002)	(0.002)
Distance to CBD	-0.029***	-0.021***
	(0.000)	(0.000)
District Fixed Effects	No	Yes
Month Fixed Effects	No	Yes
N	15205	15205
R2_Adj	0.579	0.834

Standard errors in parentheses.

* p<.1 ** p<.05 ***p<.01

Table 5: Completion Effect

	OLS ln(price)	FE ln(price)
completion*treatment	0.132***	0.032**
	(0.019)	(0.013)
treatment	-0.026**	-0.004
	(0.010)	(0.007)
constant	-9.179***	-5.863***
	(0.644)	(0.417)
Floor area	-0.003***	-0.001***
	(0.000)	(0.000)
# bedrooms	0.006	-0.009***
	(0.004)	(0.003)
# bathrooms	0.108***	0.059***
	(0.007)	(0.005)
Floor level	-0.016***	-0.011***
	(0.003)	(0.002)
Having elevator	0.131***	0.096***
	(0.006)	(0.004)
Facing south	0.044***	0.027***
	(0.006)	(0.004)
Built year	0.010***	0.009***
	(0.000)	(0.000)
Distance to subway	0.017***	0.003
	(0.002)	(0.002)
Distance to school	-0.049***	-0.056***
	(0.002)	(0.002)
School quality	0.049***	0.043***
	(0.003)	(0.002)
Distance to park	-0.036***	-0.020***
	(0.002)	(0.002)
Park star	0.007***	0.025***
	(0.002)	(0.002)
Distance to CBD	-0.033***	-0.020***
	(0.000)	(0.000)
District Fixed Effects	No	Yes
Month Fixed Effects	No	Yes
N	13750	13750
R2_Adj	0.691	0.853

Standard errors in parentheses.
* p<.1 ** p<.05 ***p<.01

Table 6: Robustness Check

	OLS ln(price)	FE ln(price)
listing*treatment	0.369***	0.068***
	(0.021)	(0.014)
remediation*treatment	0.500***	0.104***
	(0.027)	(0.017)
treatment	-0.308***	-0.073***
	(0.019)	(0.012)
constant	-8.176***	-7.987***
	(0.656)	(0.383)
Floor area	-0.003***	-0.001***
	(0.000)	(0.000)
# bedrooms	0.001	-0.017***
	(0.004)	(0.003)
# bathrooms	0.102***	0.057***
	(0.006)	(0.004)
Floor level	-0.013***	-0.009***
	(0.003)	(0.002)
Having elevator	0.092***	0.093***
	(0.006)	(0.004)
Facing south	0.045***	0.030***
	(0.006)	(0.004)
Built year	0.010***	0.010***
	(0.000)	(0.000)
Distance to subway	0.013***	0.001
	(0.002)	(0.002)
Distance to school	-0.046***	-0.055***
	(0.002)	(0.002)
School quality	0.040***	0.043***
	(0.003)	(0.002)
Distance to park	-0.036***	-0.024***
	(0.002)	(0.002)
Park star	0.003	0.024***
	(0.002)	(0.002)
Distance to CBD	-0.029***	-0.020***
	(0.000)	(0.000)
District Fixed Effects	No	Yes
Month Fixed Effects	No	Yes
N	13750	13750
R2_Adj	0.691	0.853

Standard errors in parentheses.

* p<.1 ** p<.05 ***p<.01

CHAPTER 7:

CONCLUSION

With economic development and urbanization, water degradation becomes a common issue in many cities. The study clearly shows that severely polluted water bodies like BOWBs, have a significant adverse effect on nearby housing prices. The remediation projects result in 11.6% higher unit housing prices of properties within 0.7km of a BOWB. The BOWB listing announcement also has a positive impact, which leads to unit housing prices of BOWB nearby properties being 7% higher than prices of properties within 0.7-3 km of a BOWB. The announcement of completion has a smaller impact, which leads to a 3.6% increase in unit prices of BOWB nearby housings. My study also reveals that the BOWB-affected distance on housing prices is 0.7 km. Further than 0.7km, the impact of BOWB vanishes.

Considering that Shanghai is a densely populated city with high housing prices, an 11.6% increase in unit housing prices is enormous. As reported by Shanghai Statistical Bureau, the living space per capita is 36.7 square meters and the resident population is 24.183 million at the end of year 2017. Thus, the total residential housing area is 887.52 million square meters. According to the Lianjia housing dataset, the BOWB-affected housings are about 0.9% of total residential transactions. Then, I run a back-of-the-envelope calculation that 11.6% BOWB impact times average housing prices of BOWB-affected housings in 2018 (39,100 RMB) and times 0.9% of BOWB-affected percent. The estimated BOWB remediation benefit is 36 billion RMB, which far outweighs the cost of BOWB remediation. As reported by media, the nationwide market of BOWB remediation is over one trillion RMB, which is unaffordable if only local governments bear the costs (Southern Metropolis Daily, 2018). It is necessary to unleash the market potential in BOWB remediation projects. The study provides evidence that the remediation projects are hugely beneficial and might stimulate the BOWB remediation market.

REFERENCES

Anselin, L., & Lozano-Gracia, N. (2008). Errors in variables and spatial effects in hedonic house price models of ambient air quality. Empirical economics, 34(1), 5-34.

Bajari, P., Fruehwirth, J. C., & Timmins, C. (2012). A rational expectations approach to hedonic price regressions with time-varying unobserved product attributes: The price of pollution. *American Economic Review*, 102(5), 1898-1926.

Ball, M. J. (1973). Recent empirical work on the determinants of relative house prices. *Urban studies*, 10(2), 213-233.

Bayer, P., Keohane, N., & Timmins, C. (2009). Migration and hedonic valuation: The case of air quality. *Journal of Environmental Economics and Management*, 58(1), 1-14.

Bishop, K. C., & Murphy, A. D. (2011). Incorporating dynamic behavior into the Hedonic Model.

Bishop, K. C., Kuminoff, N. V., Banzhaf, H. S., Boyle, K. J., von Gravenitz, K., Pope, J. C., ... & Timmins, C. D. (2020). Best practices for using hedonic property value models to measure willingness to pay for environmental quality. *Review of Environmental Economics and Policy*, 14(2), 260-281.

Boslett, A., Guilfoos, T., & Lang, C. (2016). Valuation of expectations: A hedonic study of shale gas development and New York's moratorium. *Journal of Environmental Economics and Management*, 77, 14-30.

Boyd, J., Ringold, P., Krupnick, A., Johnson, R., Weber, M., & Hall, K. M. (2015). Ecosystem services indicators: improving the linkage between biophysical and economic analyses. *Resources for the Future Discussion paper*, 15-40.

Boyle, K. J. (1998). Lakefront property owners' economic demand for water clarity in Maine lakes.

Can, A. (1992). Specification and estimation of hedonic housing price models. *Regional science and urban economics*, 22(3), 453-474.

Chau, K., Ma, V., & Ho, D. (2001). The pricing of 'luckiness' in the apartment market. *Journal of Real Estate Literature*, 9(1), 29-40.

Chen, W. Y. (2017). Environmental externalities of urban river pollution and restoration: A hedonic analysis in Guangzhou (China). *Landscape and Urban Planning*, 157, 170-179.

Chinese Ministry of Housing and Urban-rural Development, 2015. Work Guide for the Treatment of Black-odorous Water Bodies in Cities, Beijing.http://www.mohurd.gov.cn/wjfb/201509/t20150911_224828.html.

Chinese State Council, 2015. Action Plan for Water Pollution Prevention and Control,Beijing.http://www.gov.cn/zhengce/content/2015-04/16/content_9613.htm.

Davis, L. W. (2004). The effect of health risk on housing values: Evidence from a cancer cluster. *American Economic Review*, 94(5), 1693-1704.

Diao, M., Leonard, D., & Sing, T. F. (2017). Spatial-difference-in-differences models for impact of new mass rapid transit line on private housing values. *Regional Science and Urban Economics*, 67, 64-77.

Dubin, R. A. (1988). Estimation of regression coefficients in the presence of spatially autocorrelated error terms. *The Review of Economics and Statistics*, 466-474.

Epp, D. J., & Al-Ani, K. S. (1979). The effect of water quality on rural nonfarm residential property values. *American Journal of agricultural economics*, 61(3), 529-534.

Freeman III, A. M., Herriges, J. A., & Kling, C. L. (2014). The measurement of environmental and resource values: theory and methods. Routledge.

Freeman, R., Liang, W., Song, R., & Timmins, C. (2019). Willingness to pay for clean air in China. *Journal of Environmental Economics and Management*, 94, 188-216.

Gibbs, J. P., Halstead, J. M., Boyle, K. J., & Huang, J. C. (2002). An hedonic analysis of the effects of lake water clarity on New Hampshire lakefront properties. *Agricultural and Resource Economics Review*, 31(1), 39-46.

Goodman, A. C. (1978). Hedonic prices, price indices and housing markets. *Journal of urban economics*, 5(4), 471-484.

Juang, D. F., Lee, C. H., Chen, W. C., & Yuan, C. S. (2010). Do the VOCs that evaporate from a heavily polluted river threaten the health of riparian residents?. *Science of the total environment*, 408(20), 4524-4531.

Kroes, E. P., & Sheldon, R. J. (1988). Stated preference methods: an introduction. *Journal of transport economics and policy*, 11-25.

Linden, L., & Rockoff, J. E. (2008). Estimates of the impact of crime risk on property values from Megan's laws. *American Economic Review*, 98(3), 1103-27.

Lu J., BAI Y., AO D., et al. Analysis of regulation thoughts,measures and typical case for the black-stinking water body in Shanghai city, China[J]. *Chinese Journal of Environmental Engineering*, 2019, 13(3): 541-549

Michael, H. J., Boyle, K. J., & Bouchard, R. (1996). Water quality affects property prices: A case study of selected Maine lakes (Vol. 39). Orono, Maine: Maine Agricultural and Forest Experiment Station, University of Maine.

Muehlenbachs, L., Spiller, E., & Timmins, C. (2015). The housing market impacts of shale gas development. *American Economic Review*, 105(12), 3633-59.

Palmquist, R. B. (2005). Property Value Models. Handbook of Environmental Economics. K. *G. Maler and JR Vincent, Elseiver*, *2*.

Phaneuf, D. J., & Smith, V. K. (2005). Recreation demand models. *Handbook of environmental economics*, *2*, 671-761.

Poor, P. J., Pessagno, K. L., & Paul, R. W. (2007). Exploring the hedonic value of ambient water quality: a local watershed-based study. *Ecological Economics*, 60(4), 797-806.

Ridker, R. G., & Henning, J. A. (1967). The determinants of residential property values with special reference to air pollution. *The review of Economics and Statistics*, 246-257.

Roback, Jennifer. "Wages, rents, and the quality of life." *Journal of political Economy* 90, no. 6 (1982): 1257-1278.

Rosen, Sherwin. "Hedonic prices and implicit markets: product differentiation in pure competition." *Journal of political economy* 82, no. 1 (1974): 34-55.

Shanghai Municipal Bureau of Ecology and Environment. (2015). Shanghai Ecological and Environmental Bulletin.

Shanghai Statistical Bureau. Shanghai statistical yearbook. Beijing: China Statistical Press, (various years).

Southern Metropolis Daily. (2018). BOWB remediation market surpassing one trillion. https://www.sohu.com/a/243544120_161795.[Chinese]

Urban Surveyor (2020). Reivew of Major Housing Policies in Shanghai, 2010-209.

Wang, D., & Huang, W. (2007). Effect of urban environment on residential property values by hedonic method: a case study of Shanghai. *City Planning Review*, 31(9), 34-41.

Wang, D., & Huang, W. (2007). Effect of urban environment on residential property values by hedonic method: a case study of Shanghai. *City Planning Review*, 31(9), 34-41.

Wang, X., 2006. Hedonic Model of Shanghai Housing Prices. Tongji University [Chinese]

Wen, H. Z., Sheng-hua, J., & Xiao-yu, G. (2005). Hedonic price analysis of urban housing: an empirical research on Hangzhou, China. *Journal of Zhejiang University-Science A*, 6(8), 907-914.

Zhang, J. (2018). Emerging Consumer Cities-Mixed land use, amenities and housing prices in Shanghai (Doctoral dissertation).

Zheng, S. 2005. Shanghai Transformation. LSE Cities.