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Estimating the Social Benefits of Landfill Restoration and Redevelopment in Hong Kong: Evidence from Housing Market

評估香港堆填區清理及再利用的社會效益: 來自房屋市場的證據

Project No. 2020.A1.094.20A

Final Report

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Executive Summary

Abstract

Being one of the world's most densely populated cities, waste cleanup is one of the central missions for the public sector in Hong Kong. A major concern of waste cleanup programs is that they generate huge costs which their social benefits may not fully recover. Therefore, accurately measuring the social benefit and cost of environmental programs could have significant policy implications to the public sector. Since the 1990s, the Hong Kong government has restored 13 closed landfills, which occupy a total area of 320 hectares. Given the environment and urban health concerns, the Hong Kong government completed the landfill restoration from 1997 to 2006, and redeveloped most landfills into urban parks and green space afterwards. Not only have the landfill cleanup projects minimized the adverse impacts from landfill sites directly, but also generated many social benefits, such as improving air quality and providing local amenities to residents.

However, these cleanup programs may generate substantial costs, and it is unclear whether their social benefits can recover these costs. This study seeks to quantify the short-term social benefits of this landfill cleanup program by measuring its impact on the housing market. Using the difference-in-differences method, we find that housing prices near landfill sites increase about 2.2%, on average, within two years after landfill restoration. However, housing prices show no further change after the restored landfill sites are redeveloped into urban parks and other facilities. We argue that removal of the stigma effect is likely the main channel for housing price hikes. Through a back-of-the-envelope estimation, we find that the social benefits from housing value appreciation can sufficiently recover the program costs.

Summary on policy implications and recommendations

The estimation of the impact of landfill cleanliness on housing values has welfare implications for waste cleanup programs. We attempt to calculate the economic gains reflected in rising housing values by assuming an extremely inelastic land supply. As we find that landfill redevelopment does not have an impact on housing value changes, we only estimate the short-run economic gains from landfill restoration.

There are 12,548 total housing units in the treatment groups. The average housing value for transacted units in the treatment groups is 2.37 million HKD per unit within 2 years after policy shock, and the average value appreciation rate within two years is 2.18% (see column 2 in Table 3). Thus, the net welfare gain from rising housing value within two years equals roughly 648.14 million HKD (12,548*2.3704*0.0218). Table 1 shows that the operational cost for the landfill restoration and redevelopment program was about 71 million HKD per year. This seems to suggest that the benefits from the existing landfill cleanup program in Hong Kong have been sufficient to recover its cost in the short run. Based on our welfare analysis, we can conclude that the current landfill cleanup program is a cost-efficient policy in a high-density urban setting such as Hong Kong.

研究摘要

作為世界上人口最稠密的城市，廢物清理是香港政府的主要任務之一。廢物清理項目往往成本巨大，而所帶來的社會收益未必能夠彌補項目成本。準確評估環境項目所帶來的社會效益對公共政策有重大影響。香港共有 13 個關閉的垃圾填埋區，佔地約 320 公頃。考慮到對環境和健康的影響，政府於 1997 至 2006 年間完成了垃圾填埋場的清理，之後將填埋場重新開發為城市公園和綠地。這項環境清理項目不僅減少了填埋場對城市健康帶來的不利影響，也產生了許多社會效益，例如改善空氣和環境居住質量。

填埋場清理項目成本高昂，目前尚無研究估算此項目的社會效益。本課題旨在通過衡量填埋場清理工程對香港住房市場的影響，來量化其社會效益。基於雙重差分模型方法，通過 1991-2019 年在填埋場附近居民的住房交易數據，來計算此項目的社會效益。研究結果表明鄰近填埋場的住房價格在修復兩年內平均增值 2%。然而，如果填埋場地開發為城市公園或其他設施用地，房價並沒有明顯變化。我們認為去除污名效應是住房價格攀升的主要渠道。通過成本和收益分析，我們發現住房價值升值的社會效益足以彌補填埋場清理項目的工程成本。

對政策的影響和建議摘要

評估填埋場清理項目投資對住房價值的資本率有助於政府部門制定廢物清理項目，並有助於製定未來的環境政策。本課題通過計算住房價值增值的經濟收益，發現垃圾填埋場再開發並沒有帶來房價變化，垃圾填埋場修復項目在短期內會產生經濟收益。

經濟收益的估算基於 12548 套住房。這些住房附近的填埋場修復後 2 年，平均價值為每套 2.37 百萬港幣，增值率是 2.18%。因此，由房價增值引起的兩年內的淨社會收益大約是 6.48 億港幣。從表一得知，填埋場修復和再開發項目的工程成本大致每年 7.1 千萬。這說明了香港目前的填埋場清理項目中，短期內，清理帶來的收益足以彌補清理項目投資。基於我們的經濟效益分析，研究結論表明，在香港這樣的高密度城市，填埋場清理項目是成本效益優異的政策。

1 Introduction

The quality of the living environment is closely related to the quality of people's daily life. A good living environment including fresh air and accessible green space can improve residents' physical and mental health and promote broader social benefits (Kampa and Castanas, 2008). Conversely, a deteriorated and polluted living environment can cause many undesirable socioeconomic consequences. For example, polluted air and water can negatively impact public health and reduce life expectancy of residents (Greenstone and Hanna, 2014; Guo et al., 2019). Moreover, environmental pollution has been found to trigger many social problems such as reducing workers' productivity, slowing down economic growth, driving up crimes, and increasing social inequality (Grossman and Krueger, 1995; Zivin and Neidell, 2013).

Given these negative impacts, environmental protection has become a global public concern. To address environmental issues, public sectors in many countries have launched various policies and regulations to mitigate these negative impacts generated by pollution and environmental deterioration. For example, the US government initiated the Clean Air Act in 1970 and Clean Water Act in 1972 to abate air and water pollution (Isen et al., 2017, Keiser and Shapiro, 2019). Chinese local governments relocated their heavy industries from urban centers to less-developed areas (Zheng et al., 2014). However, the effects of environmental regulation on the improvement of urban life have been shown to be mixed and case-dependent. For instance, Greenstone and Hanna (2014) found that the water regulation in India had no measurable benefits. One concern about environmental regulations is that most programs generate huge social costs, and, at times, the social benefits do not fully cover these social costs (Jaffe et al., 1995). For example, it is costly for many heavily polluted industries to abate pollution through adopting new equipment and technology, which in turn slows down the growth of firms and employment (Greenstone, 2002). Tougher environmental regulation is found to reduce the foreign direct investment inflow (FDI) because many FDI projects are related to heavily polluted industries (Cai et al., 2016). Therefore, accurately measuring the social benefit and cost of environmental programs could have significant policy implications for the public sector.

Among all types of environmental pollutions, hazardous waste sites substantially threaten public health and living environments by producing noise and polluting air and underground water (Dolk et al., 1998). Accordingly, public sectors in many countries have launched various programs and legislation to reduce hazardous waste. For example, the European Union issued legislation to improve hazardous waste performance for European Countries (Callao et al., 2019). Chinese cities initiated a municipal solid waste source-separated collection program in 2000 (Han and Zhang, 2017). The US federal government initiated the Superfund program in 1980, which was designed to investigate and clean up about 40,000 contaminated sites including 1,600 highly contaminated sites with hazardous substances (Currie et al., 2011). All these programs are supposed to reduce the pollution and environmental contamination of hazardous waste sites. However, the evidence on the social benefits of waste cleanup in the literature is mixed and inconclusive. For example, Kiel and Zabel (2001) found the benefits from cleaning up the Superfund sites in Woburn, Massachusetts were much higher than the program cost, suggesting a positive net social welfare gain. In contrast, Greenstone and Gallagher (2008) estimated the impact of the Superfund waste cleanup program and found the benefits of waste cleanup are significantly lower than the program cost in the US. Leon et al. (2016) showed that the economic benefits from moving landfills are relatively small compared to other policies in the Spanish context.

Although vast studies have focused on the evaluation of waste cleanup programs, most quantitative research has been done in the western context. However, the conclusions drawn for the western context may not apply to other countries and cities for three main reasons. First, different ethnic groups may have different preferences and valuations for the same type of urban (dis)amenity, which may affect the results of program evaluations. Second, many western countries such as the US and Canada have abundant land resources with relatively low population density, and thus the social benefits from waste cleanup programs may be relatively low compared to high density areas such as mega cities in East Asia. Third, the results drawn from existing studies are case-dependent and inconclusive, and it is necessary to conduct a separate evaluation for waste cleanup in different settings. Accordingly, the purpose of this study is to statistically test the benefits of a landfill cleanup program in a densely populated urban setting in East Asia, and we chose Hong Kong (HK) as a case to enrich the literature on this subject.

Hong Kong is one of the densest and richest cities with the most unaffordable housing market in the world (Chang, 2018). In theory, landfill cleanup in Hong Kong should yield high social benefits since many people can be affected by hazardous waste given its densely populated settlement pattern. Since the 1990s, the Hong Kong government has restored 13 closed landfills and redeveloped most of them into parks and other recreational uses. This is an interesting case to investigate because there are several channels associated with environmental improvement. First, landfill restoration is likely to bring social benefits through pollution and contamination reduction. Second, redeveloped urban parks and green space can further improve urban amenities by promoting ecological biodiversity, providing increased space for different kinds of social interaction, and creating a sense of wellbeing with broader social benefits (Peters et al., 2010; Shores and West, 2008). However, to the best of our knowledge, existing studies have not explored the potential mechanisms that affect the benefits of landfill cleanups. The case in Hong Kong gives us the opportunity to evaluate the program benefits and examine the underlying mechanisms to see whether contamination reduction, amenity improvement, or other channels have the greatest effect.

For landfill cleanup programs, the program costs are relatively straightforward and are mainly composed of the engineering and labor costs involved in the cleanup and operation processes. However, the program benefits are difficult to evaluate in monetary terms. The literature provides several approaches to quantify the cleanup benefits. One is through the choice experiment, in which the public preference for several alternative waste management policies can be captured through a survey. For example, Leon et al. (2016) applied a choice experiment to evaluate the benefits of three waste management policies by conducting a survey among 660 individuals living close to landfill sites in the city of Las Palmas, Spain. Another popular way to measure the benefits of waste cleanup is through revealed-preference methods in which economic theory enables the identification of the willingness to pay for local (dis)amenities. As the quality of urban amenities can be capitalized in property values, many studies have applied the hedonic model to estimate an individual's valuation of urban (dis)amenities by examining changes in housing prices (Linden and Rockoff, 2008). For example, Mastromonaco (2013) found that housing prices close to Superfund sites in Los Angeles increased about 7.3% after site cleanups.

Following existing studies, this research combines data from the housing market close to landfill sites to estimate the housing price changes caused by landfill restoration and redevelopment in Hong Kong. Our hypothesis is that the house prices for housing units closer to landfill sites will increase after both landfill restoration and redevelopment, compared with housing units slightly farther from landfill sites.

1.1 Landfill Cleanup Program in Hong Kong

Hong Kong is one of the world's most densely populated cities, with 7.48 million people living in a 1,111-square km territory as of 2018 (Census and Statistics Department, 2018). Geographically, the city is bordered by Shenzhen to the north and surrounded by the China South Sea in the other directions. Over 80% of the city is mountainous with natural reserves. Its built-up area accounts for 24% of the territory, and 7% of the land is designated for residential land use (Planning Department of Hong Kong, 2018). Every year since 2011, Hong Kong has been ranked as having the most unaffordable housing market in the world (Demographia International Housing Affordability Survey, 2019). Previous studies have documented that its geographic constraints, inelastic land supply, and new immigrants from mainland China are all contributing to Hong Kong's expensive housing market (Chang, 2017, 2018)

Given such a highly dense settlement pattern and high frequency of social interaction, diseases such as the flu can spread easily among residents. In recent years, the number of cases of the flu has increased, which not only affects urban health, but also brings social costs including school closures.[1] Reducing environmental pollution and creating a clean, livable environment are critical to improving urban health and the quality of life of residents. In the past several decades, the Environmental Protection Department (EPD) of Hong Kong has initiated many programs to protect the urban environment, including improving air and water quality, reducing noise and waste, conserving natural areas, and protecting endangered species. Waste reduction and disposal is one of the central missions of the EPD. Among the many waste disposal projects, the restoration and redevelopment of closed landfills are notable.

Improving environmental quality is one of the central mission for policy makers. The landfill disposal in the 1990s is one of the government efforts towards improving the environmental quality and urban amenity. However, like most of environmental projects, landfill cleanup program is costly. The public sector has spent over 2 billion HKD for this project. Until today, the social benefit of this project is still unclear. This study tends to quantify the social

[1] The annual influenza report can be accessed through the official website of the Centre for Health Protection in HK (https://www.chp.gov.hk/en/resources/29/441.html). In Jan. 2019, the Centre for Health Protection of HK recommended seven days of class suspension for kindergartens to avoid further spread of the flu; see https://www.news.gov.hk/eng/2019/01/20190118/20190118_144131_942.html

benefits of landfill restoration and redevelopment through measuring its impact on housing market for residents living close to landfill sites.

According to the EPD website, there are 13 closed landfills in Hong Kong occupying a total area of around 320 hectares, as shown in Figure 1. As several landfill sites are located in urban districts close to large-scale neighborhoods, their negative impact on air quality and living environments has become a concern for the general public. To reduce the waste hazard, the Hong Kong government initiated a landfill cleanup program, which includes three different phases: landfill closure, restoration, and redevelopment (Environmental Protection Department, 2018). Among the 13 closed landfills, 11 sites have been redeveloped for public use. However, the cost of this program is fairly high. Table 1 summarizes the information on each landfill site including the time spent on landfill closure, restoration, redevelopment, current usage, and costs of landfill restoration. In nominal terms, in the 1996 to 2006 timeframe, the total capital cost for landfill restoration was 1.32 billion Hong Kong Dollars (HKD) and the estimated annual operation cost was 71 million HKD. Given such high costs, it is important to quantify the benefits of this program. Currently, there is a lack of program evaluation regarding the magnitude and mechanisms of the landfill cleanup program in Hong Kong.

Table 1: Information on Landfill Cleanup Program in Hong Kong

Name	Area (ha)	Close	Restor-ation	Redevel-opment	Function	Capital Cost (HK$m)	Operation Cost (HK$m/year)
Jordan Valley	11	1990	May-98	Mar-10	Park		
Ma Yau Tong Central	11	1986	May-98	Jan-11	Sitting		
Ma Yau Tong West	6	1981	May-98	Sep-11	Sitting	249	9
Sai Tso Wan	9	1981	May-98	Feb-04	Recreation		
Ngau Chi Wan	8	1977	Dec-00	Aug-09	Park		
Siu Lang Shui	12	1983	May-00		Green Zone		
Ma Tso Lung	2	1979	May-00	Aug-00	Hospital Use	332	21
Ngau Tam Mei	2	1975	May-00		Green Zone		
Gin Drinkers Bay	29	1979	Sep-00	Oct-09	Park		
Tseung Kwan O Stage I	68	1995	Jan-99	Jun-12	Footpath	369	21
Tseung Kwan O Stage II/III	42	1994	Jan-99	May-05	Training field		
Shuen Wan	55	1995	Dec-97	Apr-99	Golf	168	5
Pillar Point Valley	65	1996	Jul-06	Jul-16	Shooting	199	15
Total	320					1,317	71

Note: The nominal capital and estimated operation cost refer to the landfill restoration rather than landfill closure and redevelopment. All information can be found in EPD official website: https://www.epd.gov.hk

Among the three phases of landfill cleanup (closure, restoration, and redevelopment), each may have a different effect on nearby housing values. We expect that both landfill closure and restoration can reduce environmental pollution. Landfill redevelopment is potentially associated with additional local amenities, such as public parks. However, we are unable to estimate the effect of landfill closure on housing values due to data limitations. As shown in Table 1, most landfills were closed in the 1980s. Our housing transaction data start from 1991 (more on this in the following section) and the early data are not available. Four landfill sites were closed between 1994 and 1996; however, we do not find any housing estates developed before 1996 located within a 30-minute walk from those landfill sites. Thus, we are unable to examine the causal effect of landfill closures on housing values. Therefore, the following section only examines the effect of landfill restoration and redevelopment on housing values.

The impact of this project is threefold. First, the findings of this study can be used for project evaluation, which enhances our understanding of the generated social benefits for the landfill restoration and redevelopment projects. Second, the findings provide a useful reference for the public sector to justify future environmental protection practices in Hong Kong. Third, the findings of this study contribute to the academic literature on the benefits of environmental improving projects, especially in high-density contexts such as that of Hong Kong.

2 Objectives

1. Build an adaptable database to analyze the social benefits of landfill cleanup program in Hong Kong;
2. Develop economic models to evaluate the social benefits of landfill cleanup program;
3. Quantify the magnitude of social benefits from housing market in Hong Kong;
4. Conduct a cost and benefit analysis for the landfill cleanup program;
5. Propose important policy suggestions based on the results of this study.

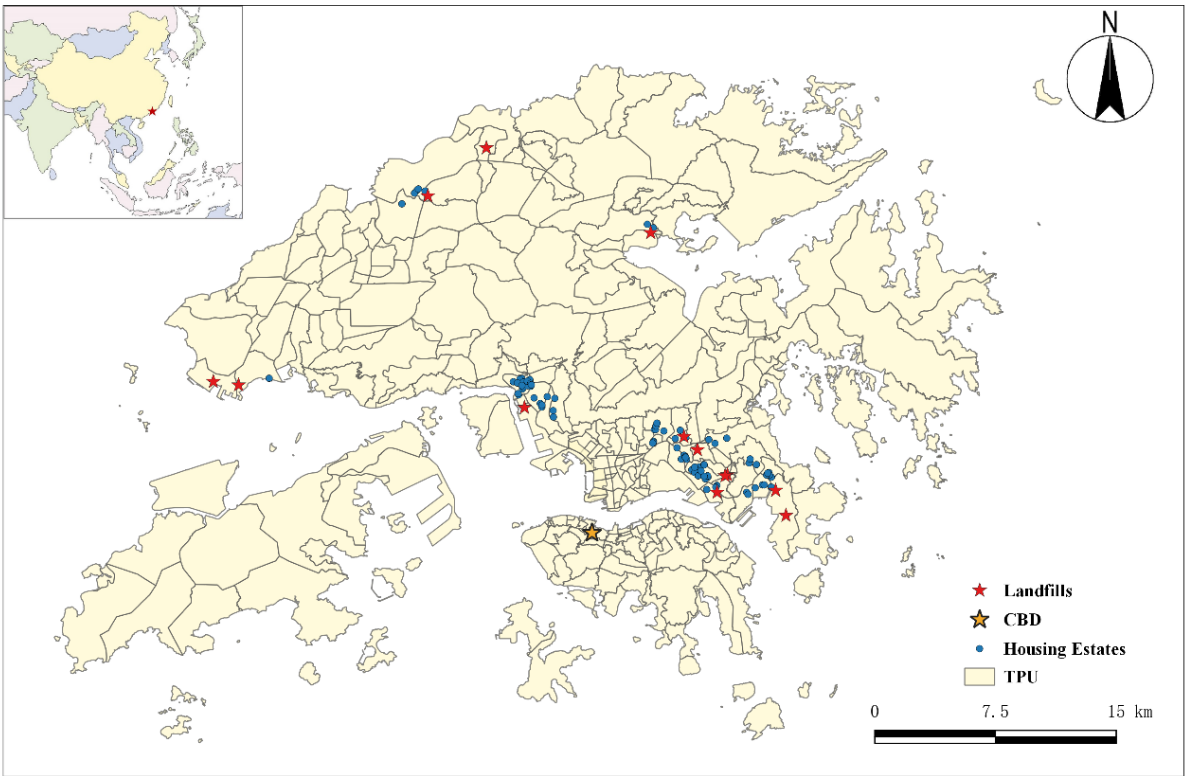
3 Research Methodology

This section introduces the empirical model and data sources. We employ the difference-in-differences (DID) method to examine housing value changes due to landfill cleanup. We focus on housing units closer to landfill sites (defined as a 1.2 km walking distance to a site) compared to housing units slightly farther away (defined as a 1.2–2.4 km walking distance to a site).

3.1 Data

This study relies on two main datasets: housing transactions and the location of landfills. The first dataset is housing transaction data purchased from EPRC Ltd., the largest housing data vendor in Hong Kong, covering all housing transactions since 1991. There are four main types of housing transactions in Hong Kong: estates, single buildings, village houses, and public housing. Estates and single buildings are the main component of private housing in Hong Kong. Estates are defined as having at least two building towers. Currently, there are about 1,000 estates and 30,000 single buildings in Hong Kong; however, estates are more liquid because they cover about two-thirds of the housing transactions according to EPRC's records. Village houses are generally located in suburban districts, are built by farmers, and have two to three floors. A public housing transaction has to satisfy various government regulations, and its transaction price is unlikely to reveal its market value. Similar to Chang and Li (2018), this study only examines housing transactions within estates because they contribute about 2/3 of housing transaction. Each transaction record includes detailed information on the name of the housing estate, floor and unit number, street level address, transaction price and date, size and age of transacted unit, number of rooms, and buyer identity. The nominal unit transaction prices across different time periods are not directly compared without adjusting for inflation. To control inflation, we adjust the normal price by the monthly consumer price index. We also measure the closest distance of each housing estate to local amenities including metro stations and local public schools.

The second dataset comprises the locations of the 13 closed landfills, with detailed addresses obtained from the EPD official website (www.epd.gov.hk). After we geocoded all landfills in a GIS environment, we selected housing estates close to those landfills. Chang et al. (2019) argued that Hong Kong is a mountainous city; the Euclidean straight-line distance is very misleading and cannot capture actual spatial relationships. Instead, the real travel distance/time extracted from the Google Map API database is more accurate for revealing spatial patterns. Following their approach, we measure the spatial distance by calculating the actual walking distance/time from each estate to its closest landfill using the Google Map API database. We assume the actual walking distance to landfills based on the real street network is more relevant to the risk perception of residents. The literature suggests that the negative impact of waste sites on property values can come from several hundred meters to 2–3 km, depending on the size of the contaminated site (Currie et al., 2015). In this study, we incorporate the housing estate data near landfill sites based on two criteria. First, the housing estates have to be located within 30-minute (or 2.4 km) walking distance from an existing landfill site. If the distance is too large, the effect of landfill will be trivial. Conversely, if the distance is too small, we would not have enough data for the empirical exercise. Second, the estates had to be constructed before the landfill restoration; otherwise, we would not get a causal inference using the DID approach. Ultimately, we identified two dozen housing estates, and their spatial relationships with landfills are shown in Figure 1.



Note: The location of 13 closed landfills are from the Environmental Protection Department of Hong Kong.

Figure 1: Spatial relationship between housing estates and their close landfills

Existing studies apply a two-year window to quantify the value appreciation of amenity changes on housing price (Linden and Rockoff, 2008). Therefore, we summarize the dependent variable, variable of interest, and housing characteristics based on a time window of two years, before and after the landfill restoration and redevelopment, as shown in Table 2. We also define the housing estates within a 1.2 km walking distance of the closest landfill as the treatment group, and other estates located 1.2–2.4 km to the closest landfill as the control group. The variable of interest is the interaction term Treat*After. Table 2 shows that 13.6% of the units within the treatment group were transacted after landfill restoration, and 18.2% of units were transacted after landfill redevelopment.

Table 2: Variable Definitions and Summary Statistics

	Description	Landfill Restoration	Landfill Redevel-opment
Dependent variable			
Total Price	Total unit price, HKD million	2.89 (1.35)	1.93 (0.828)
Variable of Interests			
Treat	Binary, 1=transaction within 1.2 km of landfill site, 0 otherwise	0.48 (0.50)	0.36 (0.48)
After	Binary, 1=transaction after landfill cleanup, 0 otherwise	0.33 (0.47)	0.49 (0.50)
Treat x After	Binary, 1=transaction within 1.2 km of landfill site after landfill cleanup, 0 otherwise	0.14 (0.34)	0.18 (0.39)
Housing Characteristics			
GFA	Gross floor area, square foot	729.83 (149.35)	681.59 (148.90)
Age	Age of unit when sold	7.83 (4.03)	16.26 (6.18)
Floor	Floor number	15.41 (9.05)	17.57 (11.02)
Dis_Landfill	Walking distance to closest landfill, meters	1,385 (355)	1408 (489)
Dis_CBD	Straight distance to the CBD, meters	8,489 (1773)	9,224 (1,698)
Dis_Metro	Straight distance to the closest metro stations, meters	488 (437)	536 (378)
Dis_School	Straight distance to the closest public primary schools, meters	494 (296)	377 (274)
Observation		8,526	6,916

Note: This table summaries variables based on the time of landfill restoration and redevelopment. The first column covers housing transactions within 2 years before and after landfill restoration, while the second column summarizes housing transactions within 2 years before and after landfill redevelopment. Standard deviations are in parentheses. Year and month dummies as well as housing estates dummies are not included in the summary statistics. The Dis_CBD, Dis_MTR and Dis_School are the Euclidean distance computed by using GIS.

3.2 Empirical Methods

In the seminal study by Rosen (1974), the housing price was decomposed into a bundle of attributes including housing characteristics, such as floor space and age of building; location factors, such as distance to city business district (CBD) and closest public transportation stops; and neighborhood amenities, such as green space. The landfill cleanup project in Hong Kong provides amenity value to neighborhoods, which could affect housing prices. Beyond these observed features, many unobservable features were found to affect housing prices, such as perceptions of stigma in a neighborhood or unit, attitudes toward different ethnic groups, and perceived neighborhood crime risks (Chang and Li, 2018; Linden and Rockoff, 2008). Therefore, the choice of housing unit in an area reflects the household's preference for a bundle of observed and unobserved local factors. The hedonic approach is capable of estimating marginal willingness to pay for a particular local attribute, and many studies have examined the relationship between a local (dis)amenity and housing values, such as accessibility, pollution, and school quality (Black, 1999; Chang and Murakami, 2019; Chay and Greenstone, 2005).

However, there are two concerns when estimating the preference on a variable of interest using the hedonic approach. First, the changes in local (dis)amenities can be correlated with unobservable factors, and the ordinary least squares (OLS) regression is likely to yield biased results due to omitted variable concerns (Epple, 1987). Second, the long-run housing supply is perfectly elastic, and the changes in housing demand will reflect housing quantities rather than housing prices. Even without any adjustment in housing supply, long-run housing price changes due to exogenous shocks are still difficult to identify because households may have sufficient time to adjust their behavior. Thus, more unobserved and omitted variables are likely to bias the estimation in a long-run horizon.

To overcome omitted variable concerns, recent studies are increasingly employing other approaches by conducting causal inference in a quasi-experimental setting, such as difference-in-differences (DID) and the regression discontinuity method (Zheng et al., 2019). For example, Chang and Li (2020) applied the DID method to measure environmental regulation and land prices in Shanghai. The central idea is to examine the effect of the exogenous change in local factors on housing values. To ensure the accuracy of empirical estimations, many studies examine the short-run (typically within a two-year window) effect of local amenity changes on housing values (Linden and Rockoff, 2008). The idea is that land supply is inelastic in the short run, and the effect of local amenity changes should be reflected in the housing price rather than quantity.

In this study, the original landfill sites may not be randomly assigned across different districts. They may be located in low-income or low-density neighborhoods, and developers may not be willing to develop high occupancy and high-quality buildings nearby. Thus, the simple cross-sectional OLS regression cannot address the selection and omitted variable issues. Similar to existing studies (Linden and Rockoff, 2008), we apply the DID approach to uncover the causal effect of landfill restoration and redevelopment programs on nearby property values within a two-year window. The baseline model is shown in Equation (1):

$$P_{ijt} = a_0 + a_1 Treat_j * After_t + a_2 X_i + \mu_j + \tau_t + \varepsilon_{it} \qquad (1)$$

where P_{ijt} is the transaction price of housing unit *i* in estate *j* at time *t*. $Treat_j$ is a dummy variable that equals one if the housing estates are close to landfill sites, and zero otherwise. Here we define the treatment group as housing estates located within a 15-minute walk (or equivalent to 1.2 km walking distance as shown in the Google Map API) from a landfill; and the control group as housing estates located a 15–30 minute walk (or 1.2–2.4 km walking distance) from a landfill. $After_t$ is a dummy variable that takes the value of one if the units are transacted after the landfill restoration or redevelopment, and zero otherwise. X_i is a control vector of housing characteristics and local amenities including unit size, floor number, age, and distance to the closest metro station. The description of these variables is provided in Table 2. μ_j is a housing estate level fixed effect that captures specific time-invariant locational characteristics and unobservable housing estate factors, and τ_t is the year and month fixed effect. ε_{it} is the error term. The coefficient a_1 is our research interest, which reveals the causal impact of landfill cleanup on housing price changes. The coefficient a_0 is the intercept of the formula and a_2 is the coefficient of housing characteristics.

4 Research Findings

We first show the baseline result of the DID regression to demonstrate the average effect of landfill restoration and redevelopment on housing values. We find that the housing price increases significantly after landfill restoration, while the value has no further change due to landfill redevelopment. Then, we explore the temporal effect, which can reveal how quickly the housing market responds to a landfill cleanup and whether the effect is persistent. Lastly, we provide a robustness check to show our results remain stable by changing the treatment and control groups through a continuous DID regression.

4.1 Baseline Results

Table 3 reports our baseline regression results regarding the effect of landfill restoration and redevelopment on housing values within 2 years of program implementation. The dependent variable is the natural logarithm of unit housing values. The first two columns report the effect of the landfill restoration on housing price. Column (1) reports the pooled OLS regression result with the housing characteristics and time fixed effect.[2] It also shows the elasticity of housing values with respect to several housing attributes, including unit size, floor level, age of units, distance to CBD, and distance to the closest metro stations. All these elasticities are highly significant and consistent with our expectations. Overall, the model explains the data variation well and R^2 is about 0.95. However, the main coefficient is about 0.01 and not significant, which indicates that landfill restoration does not have much effect on housing prices. As mentioned earlier, this result from the OLS regression cannot be interpreted as a causal effect due to potential selection and omitted variable issues.

To evaluate the causal effect of landfill restoration on housing values, column (2) of Table 2 shows the DID estimation by employing Equation (1). We control the housing-estate-level fixed effect and year and month fixed effect. The interaction of Treat*After is our research interest. As the time-invariant variables (distance to CBD and the closest MTR stations) are highly collinear with the estate fixed effect (the variance inflation factor is over 400), we drop the variables in the regression. Given the concern of serial correlation of the unit transaction price within the same housing estate, the standard error is clustered at the housing estate

[2] The distance of housing estates to local public schools is highly correlated to the distance to CBD. The variance inflation factor (VIF) for the distance to local public school is about 10. Due to the multicollinearity concern, we drop this variable in the regression. The detecting multicollinearity using VIF can be found in the following website: https://online.stat.psu.edu/stat462/node/180/.

level. The result shows that housing values go up 2.2% within a two-year time window. The result is very significant, and the R^2 is about 0.98. Similarly, we use the same pooled OLS and DID examination to evaluate the effect of the landfill redevelopment on housing values, which are reported in columns (3) and (4). We find the landfill redevelopment has no effect on changes in housing values.

Table 3: Baseline Regression Results

	Landfill Restoration		Landfill redevelopment	
	(1) Pooled OLS	(2) DID	(3) Pooled OLS	(4) DID
Treat	0.0098		0.022	
	(0.0076)		(0.041)	
Treat*After		0.0218**		-0.0115
		(0.008)		(0.0088)
ln(Gfa)	1.0989***	1.0454***	1.209***	1.2227***
	(0.0061)	(0.0876)	(0.0843)	(0.0701)
ln(Floor)	0.052***	0.0575***	0.0601***	0.0672***
	(0.0014)	(0.0028)	(0.0052)	(0.0047)
ln(Age)	-0.2913***	-0.2092***	-0.201**	-0.3048***
	(0.005)	(0.028)	(0.0532)	(0.0984)
ln(Dis_CBD)	-0.3463***		-0.7691***	
	(0.0275)		(0.1884)	
ln(Dis_Metro)	-0.0556***		-0.0743***	
	(0.0027)		(0.013)	
Year and Month Fixed Effect	Yes	Yes	Yes	Yes
Estate Fixed Effect	No	Yes	No	Yes
R2	0.954	0.977	0.876	0.946
Observation	8526	8526	6916	6916

Note: This table reports the pooled-OLS and DID regression results with 2 year time windows. The column (1) and (3) show the results from OLS regression, while (2) and (4) report the results from DID regression. Standard errors are in parentheses and clustered at housing estate level. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively.

A valid DID regression is based on the parallel trends assumption. We test the pre-trend assumption by including the interactions of the time dummies and the treatment indicator for the one-year pre-treatment period, a method that follows Autor (2003). As the coefficients on the interaction term of the one-year pre-treatment period are not significant, we can conclude that the parallel pre-trend assumption is valid.

4.2 Temporal Effect

Based on the baseline DID regression results, we explore the temporal effect of the landfill cleanup program on housing values. The purpose of this examination is to understand how fast the housing market responds to landfill cleanups and whether the effect varies by using different time windows. To be consistent, we use the same pre-policy two-year period data as the control group, and then use different post-policy treatment windows to explore the temporal effect of policy shock. The results are reported in Table 4. The first four columns show the housing value appreciation due to the landfill restoration given different time windows. We find housing values increase immediately after the landfill restoration even within a three-month post policy window. Also, all results by expanding time windows are quite significant and persistent with a similar coefficient about 2.5%. Similarly, we estimate the effect of the landfill redevelopment on housing prices in different time windows, as shown in columns (5) to (8). All results are slightly negative, but none are very significant.

Table 4: Temporal effect of landfill cleanup on housing values

	Landfill Restoration				Landfill Redevelopment			
	(1) 3 months	(2) 6 months	(3) 1 year	(4) 2 years	(5) 3 months	(6) 6 months	(7) 1 year	(8) 2 years
Treat*After	0.027***	0.028***	0.024***	0.022***	-0.004	-0.002	-0.006	-0.012
	(0.005)	(0.006)	(0.007)	(0.008)	(0.013)	(0.010)	(0.008)	(0.009)
lnGfa	1.046***	1.042***	1.044***	1.045***	1.236***	1.235***	1.230***	1.223***
	(0.086)	(0.086)	(0.085)	(0.088)	(0.091)	(0.083)	(0.078)	(0.070)
lnFloor	0.058***	0.058***	0.058***	0.058***	0.067***	0.067***	0.067***	0.067***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.006)	(0.005)	(0.005)
lnAge	-0.207***	-0.207***	-0.210***	-0.210***	-0.261*	-0.273**	-0.283**	-0.305***
	(0.021)	(0.022)	(0.023)	(0.028)	(0.130)	(0.127)	(0.113)	(0.098)
Year & month fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estate fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.973	0.974	0.975	0.977	0.938	0.941	0.940	0.946
Observation	6,133	6,593	7,348	8,526	4,022	4,430	5,386	6,916

Note: This table reports the DID regression results with different time windows. Standard errors are in parentheses and clustered at housing estate level. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively.

4.3 Robustness Checks

Another concern with the results shown in Tables 3 and 4 is that the assignments between the treatment group (0–1.2 km) and control group (1.2–2.4 km) are slightly ad hoc. Changing the threshold (1.2 km) may change the regression results. To address this, we conduct a robustness check by running a DID model with continuous treatment distances for housing estates within 2.4 km from the closest landfill. The regression is largely the same as before, but the interaction term is After* log(Dis_landfill). The results are reported in Table 5. The first four columns show that the coefficients on the interaction terms are significantly negative given different time windows. The interpretation is that after the landfill restoration, the housing prices tend to decline as the distances between the housing estates and the landfills increase. In other words, the housing units close to the landfills see a price hike caused by landfill restoration compared with the units farther away. Similarly, columns (5) to (8) show that landfill redevelopment has no effect on housing prices, as all the coefficients on the interaction terms are close to zero. Notably, all coefficients on the housing attributes (Gfa, Floor, Age) and R^2 in Table 5 are quite close to the results shown in Table 4, which implicitly suggests that our estimation is valid and robust.

In summary, we find landfill restoration has significant impacts on nearby housing values. However, landfill redevelopment green space has no further value effect on housing price. One explanation is that Hong Kong is a green city as over 80% of the territory is mountainous and natural reserve, and thus the marginal value of additional green space to housing price could be relatively low.

Table 5: Robustness Check

	Landfill Restoration				Landfill Redevelopment			
	(1) 3 months	(2) 6 months	(3) 1 year	(4) 2 years	(5) 3 months	(6) 6 months	(7) 1 year	(8) 2 years
After*ln(Dis_Landfill)	-0.011** (0.005)	-0.013** (0.005)	-0.014** (0.005)	-0.017** (0.006)	-0.001 (0.001)	-0.001 (0.001)	0.001 (0.002)	0.004 (0.002)
lnGfa	1.045*** (0.086)	1.041*** (0.085)	1.043*** (0.085)	1.045*** (0.087)	1.236*** (0.090)	1.235*** (0.083)	1.229*** (0.078)	1.223*** (0.070)
lnFloor	0.057*** (0.003)	0.057*** (0.003)	0.058*** (0.003)	0.057*** (0.003)	0.067*** (0.005)	0.067*** (0.006)	0.067*** (0.005)	0.067*** (0.005)
lnAge	-0.207*** (0.021)	-0.207*** (0.022)	-0.209*** (0.024)	-0.209*** (0.028)	-0.261* (0.130)	-0.273** (0126)	-0.284** (0.112)	-0.305*** (0.097)
Year & month fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estate fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.973	0.974	0.975	0.977	0.938	0.941	0.940	0.946
Observation	6,133	6,593	7,348	8,526	4,022	4,430	5,386	6,916

Note: This table reports the DID regression results with continuous treatment distance. Standard errors are in parentheses and clustered at housing estate level. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively.

5 Policy Implications and Recommendations

This section seeks to explore the potential mechanisms of landfill cleanup programs on housing values, and then conducts a back-of-the-envelope estimation to evaluate the social welfare of programs.

5.1 Potential Mechanisms

Existing studies have not examined the potential mechanisms for how the benefits of waste cleanup are capitalized into housing values. There are three potential mechanisms affecting an individual's willingness to pay for housing in most waste disposal program areas. The first is the improvement in housing and neighborhood quality (Ahlfeldt et al., 2017). The second is the improvement in the living environment, such as improved air quality, a better view, or a new public space for recreational use (Panduro and Veie, 2013). The third is the removal of the stigma effect, which is the psychosocial impact of being located close to hazardous waste sites on housing values (Chang and Li, 2018). We argue that the removal of the stigma effect is likely to be the main mechanism driving the housing price increase due to the following reasons:

First, we can rule out the mechanism of improvement in neighborhood quality. Appendix 2 shows the balance table for the observable housing characteristics and local amenities within the treatment and control groups. We find the observable housing characteristics and local amenities have nearly no changes after landfill restoration and redevelopment. As our DID regressions control for both the housing estate level fixed effect and year and month fixed effect, all unobservable factors on housing and neighborhoods have been absorbed by those fixed effects. Thus, the changes on housing and neighborhood quality (both observable and unobservable characteristics) are unlikely to be the main channels that contribute to immediate housing price hikes right after a landfill cleanup.

Second, the redevelopment of landfills into urban parks and public facilities has no real impact on housing values, which seems to suggest that improvements in the living environment from landfill restoration and redevelopment are not the main channels influencing housing values. There could be other unobservable environmental improvements which may improve urban health. However, environmental improvement often generates long-term benefits for residential health. As we find that the housing values immediately appreciate near 2.7% within 3 months of landfill restoration (see Table 4, column 1), this effect is unlikely to be attributed to the improvement in residential health, at least in the short run.

The third important channel affecting housing price could be the psychosocial impact of waste disposal facilities on nearby residents (Elliott et al., 2004; Tuan and MacLaren, 2005). For example, McClelland et al. (1990) documented that experts judged the health risks of the landfills in Los Angeles to be very small; however, residents exhibited strong concerns about the risks of being close to a landfill site. The fear of potential risks can be much larger than the actual risk, and existing studies term this subjective risk perception the stigma effect (Messer et al., 2006). Many studies have examined the stigma effect of environmental contamination on housing values (McCluskey and Rausser, 2003; Taylor et al., 2016). In Hong Kong's housing market, the stigma effect was found to play an important role in housing values. For example, Chang and Li (2018) examined the impact of unnatural death such as suicide on housing values in Hong Kong. They found that housing value declined about 25% after an unnatural death occurred in a unit. They concluded that the large price drop was due to the stigma effect rather than other channels. As we find the improvement of housing quality and living environment cannot explain the housing price hike, it suggests the stigma effect is a likely mechanism for the price effect on housing values, although more evidence is necessary to verify this.

5.2 Welfare Implication

The estimation of the effects of landfill cleanliness on housing values has welfare implications for waste cleanup programs. In the US, scholars have shown a strong interest in conducting cost-benefit analyses for waste cleanup programs. However, such estimations are quite difficult and we still have not seen sufficiently rigorous program evaluation. Greenstone and Gallagher (2008) offered three reasons such a welfare analysis is not easy. First, the consistent estimation of the hedonic price schedule is challenging due to omitted variables. Second, inferring the residents' bid function has been undermined by taste-based sorting. Third, there is a lack of complete information for estimating the bid function for all consumers and the cost function for all suppliers in the economy.

In short, a rigorous welfare analysis requires knowledge of the shape of both the supply and demand curves (Greenstone and Gallagher, 2008), and we do not have a credible strategy to underpin the supply and demand functions separately. In this situation, the welfare estimation requires ad hoc assumptions on the elasticities of supply and demand. Given these difficulties, we attempt to calculate the economic gains reflected in rising housing values by assuming an extremely inelastic land supply. As we find that landfill redevelopment does not have an impact on housing value changes, we only estimate the short-run economic gains from landfill restoration. This back-of-the-envelope estimation is based on the following calculation shown in Equation (2):

Housing value appreciation = Number of housing units in treatment group * average housing values * value appreciate rate. (2)

There are 12,548 total housing units in the treatment groups. The average housing value for transacted units in the treatment groups is 2.3704 million HKD per unit within 2 years after policy shock, and the average value appreciation rate within two years is 2.18% (see column 2 in Table 3). Thus, the net welfare gain from rising housing value within two years equals roughly 648.14 million HKD (12,548*2.3704*0.0218). Table 1 shows that the operational cost for the landfill restoration and redevelopment program was about 71 million HKD per year. This seems to suggest that the benefits from the existing landfill cleanup program in Hong Kong have been sufficient to recover its cost in the short run. Based on our welfare analysis, we can conclude that the current landfill cleanup program is a cost-efficient policy in a high-density urban setting such as Hong Kong.

5.3 Policy Implication

In evaluating environmental policies, two criteria are often taken into consideration – efficiency and equity. Efficiency is related to cost-effectiveness, which is an indication of whether the policy can produce the maximum environmental improvement for the cost of the policy. From a social welfare viewpoint, the results of this study suggest the cost-efficiency of the existing landfill cleanup program that the costs of the cleanup programs can be sufficiently recovered from the appreciated housing values.

Equity, on the other hand, concerns about how the benefits and costs of environmental improvement are distributed among members of the society. No doubt that all residents near the landfill sites have benefited from the improved living environment after landfill restoration projects. Unfortunately, because of data constraint, we were not able to capture and evaluate this kinds of benefits in our analytical model. From an equity point of view, this study suggests that a large proportion of the benefits generated from the cleanup projects are reflected in the appreciation of housing values. This implies that the direct beneficiaries are mostly private property owners. One implication would be that the government could prioritize restoring landfill sites that are near a high concentration of public housing estates, so that the appreciated housing values could be retained in the public sector.

Another implication arises from the insignificant effect of redevelopment stage on housing prices. As we mentioned before, one landfill cleanup project in Hong Kong usually experiences three phases—closure, restoration and redevelopment—each happening in different year and all phases taking multiple years to complete. Our DID models can only assess the impacts of the second and third phases on housing prices. The findings suggest that housing prices increased after the restoration stage; while housing prices showed no significant impact caused by the redevelopment stage of the project. This means that the private real estate market around landfill sites has well-responded to the cleanup project at its second restoration stage. It is possible that the benefit of redevelopment may be realized over a longer period (more than three years) or at a larger scale beyond the 2.4 km buffer zone from the landfill site to the estate. As this area is beyond the scope of our study, it leaves rooms for further research.

6 Conclusion

We examined the short-term social benefits of the landfill restoration and the redevelopment projects in Hong Kong by measuring the effects on the housing market. Through a DID estimation, we concluded that landfill restoration increases housing prices for units close to the landfill with an appreciation rate of about 2.2% within two years. However, the landfill redevelopment has no effect on changes in housing values. We argue that the housing value appreciation was not due to improvements in housing, neighborhoods, or environmental quality but likely was a result of the removal of the stigma effect. We also completed a cost–benefit analysis and found the program benefits are sufficient to recover its costs in the short run.

This paper contributes to the literature in several ways. First, most studies in this field are focused on countries or cities with abundant land resources, while our study evaluates the benefits of waste cleanup in the highly dense urban setting of Hong Kong. Second, many studies estimate the social benefits of environmental protection programs, but few have discussed or identified the potential underlying mechanisms; our study investigates the potential mechanisms affecting housing prices. Third, our cost–benefit analysis suggests that the short-term benefits of landfill restoration are sufficient to cover the program's operational costs in Hong Kong; thus, our results enrich the literature on evaluations of waste cleanup programs. Last, our findings have important policy implications and can provide a useful reference for governments to justify future environmental protection practices in Hong Kong or other highly dense urban contexts.

We also need to highlight several limitations of this study and future challenges. First, we are unable to measure the causal effects of landfill closures on housing values due to data limitations. Second, the housing market can only partially tell the actual story, especially as our measure focuses on short-term effects. The long-run effect is even more important, but that measurement has to be conducted in different dimensions. Third, the landfill cleanup program may generate different kinds of social benefits which are not captured in this study. For example, it may have a causal effect on improvements in urban health, particularly for residents living nearby. If that is the case, the program will contribute to the accumulation of human capital, and more social benefits would be expected after landfill restoration, such as a better labor market. Fourth, our welfare analysis is not perfect. Other approaches may be adopted for better estimation and program evaluation. Fifth, although we argue the removal of the stigma effect is likely to be the main channel for housing value appreciation, more direct evidence is needed. Lastly, the method used here is based largely on partial equilibrium. A general equilibrium approach is expected to yield a more comprehensive evaluation of environmental protection programs. This research is left for future studies.

7 Public Dissemination of Research Findings

The findings of this project have been presented in a paper titled "Waste disposal and housing price: new evidence from the landfill clean-up program in Hong Kong," which is published by *Journal of Environmental Planning and Management*, a top-tier peer-reviewed journal in the field of development studies. The citation of the paper is: Chang, Zheng, Weifeng Li, Xin Li, and Chenghao Deng. 2021. "Waste disposal and housing price: new evidence from the landfill clean-up program in Hong Kong" *Journal of Environmental Planning and Management* 64(10), 1795-1815. DOI: 10.1080/09640568.2020.1838265. The paper was also presented at the SMU conference on Urban and Regional Economics, Singapore, organized by the School of Economics, Singapore Management University in December, 2020.

Appendix 1. Pre-trend assumption test

	Landfill restoration	Landfill redevelopment
Treat * 1 year before	0.008	0.015*
	(0.92)	(1.99)
Treat * 1 year after	0.023***	0.002
	(5.17)	(0.22)
Treat * 2 year after	0.0291***	0.0107
	(3.55)	(0.71)
Housing characteristics	Yes	Yes
Year and Month	Yes	Yes
Estate Fixed	Yes	Yes
R2	0.977	0.946
Observation	8526	6916

Note: We test the pre-trend assumption by including the interactions of the time dummies and the treatment indicator for the 1 year pre-treatment period, a method following Author (2003). As the coefficients on the interaction term of the 1 year pretreatment period is not very significant, we can conclude the parallel pretrend assumption is largely held. Standard errors are in parentheses and clustered at housing estate level. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively.

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