Closure, Remediation and Maturation: The Case of Freshkills Landfill

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Abstract
On March 22, 2001, Freshkills Landfill in Staten Island, NY closed after 60 years of operations. As the world's former largest landfill, the site received over 150 million tons of garbage during filling operations and is without a doubt a central consideration in planning policy and the housing market. This research focuses on measuring the impact of landfill closure on housing prices and pays particular attention to a critical methodological factor that is often ignored in the land-use literature: the effect of maturation. Maturation of market characteristics may be a natural and inevitable condition in the housing data, thus the analysis would greatly benefit from identifying the extent to which model results are related to end of operations/remediation and maturation. By systematically testing regression windows before and after the landfill closure, the results suggest that the earliest statistically significant changes in the distance-price gradient, the principal measure of landfill impact, can be observed at +/- 600 days around the closure date—a fast impact of within 1.7 years. However, 12% of covariates are found to be matured. The results also find that the distance-price gradient was reduced from 5.9% increase in house sales price per mile in the pre-closure period to 3.9% per mile.

Keywords*:* Hedonic regressions; environmental externality; landfills; housing values
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1. OVERVIEW

Originally opened by Robert Moses in 1948 as a 'temporary' landfill in a rural region (Miller, 1998), the Freshkills Landfill grew to behemoth proportions eventually receiving over 29,000 tons of garbage per day (NYSDPR). In response to public demands and changing environmental standards, Gov. George Pataki signed an emergency order in 1996 to close Freshkills Landfill by December 31, 2001 (NYSDEC, 2001). By March 22, 2001, the last barge load of garbage arrived at the site.

While a common theme in the environmental literature is the generalizable impact of undesirable land use, previous studies have failed to establish a common range for the value of environmental amenities. An environmental amenity is a feature that enhances, adds value or desirability to real estate. Conversely, a disamenity may detract from the value of real estate. In the case of Freshkills, it may be reasonable to conclude that the landfill would impose a negative regional impact; however, the precise estimate of environmental disamenities on residential property are often confounded by a mix of amenities and disamenities that may be collinear with the landfill impact. When evaluating the value for environmental quality, a commonly utilized method is the hedonic approach in which it is assumed that a good or service can be decomposed into its characteristic values (Rosen, 1974). Only upon successfully controlling for relevant characteristics can a researcher attribute the direction and magnitude of impact from neighbourhood amenities and the landfill.

The primary focus of this paper is to build upon the hedonic framework in order to estimate the value of environmental amenity in the residential neighbourhoods surrounding the world's former largest landfill located in Staten Island, NY. In particular, this research is concerned with building the necessary statistical support to establish a causal argument on the effect of landfill operations and subsequent closure. An area that is consistently overlooked in hedonic modelling is the effect of maturation, or the influence of natural changes or trends in the underlying characteristics of a housing market. When using cross-sectional data over time, the causal power is thinned as the data is not one single time series; therefore, it is ever more important to ensure that the analysis compares 'apples to apples'.

Using the end of filling operations as a policy intervention, the research first examines the comparability of housing covariates data set for various time windows around the intervention date, which is necessary to gauge the potential that distance variables are influenced by unaccounted paradigm shifts in housing markets. Upon determining the comparability of the sample before and after the intervention, the work then focuses on determining if and when did the housing market benefit from the end of filling operations and the subsequent closure construction efforts. A simple systematic approach is utilized to identify statistically significant discontinuities in the price-distance gradient.

2. **SITE OVERVIEW**

Located approximately 5 miles south of Downtown Manhattan, Staten Island has developed on a course that is unique in the context of New York City. Until the early 1960's, the Island was characterized as rural and agricultural with some urban presence in the northern shore of the island. Commuting options for residents were constrained by the lack of a direct crossing; residents were required to ride the Staten Island Ferry in order to travel directly to Brooklyn and Manhattan. The opening of the Verrazano-Narrows Bridge in 1964 vastly improved mobility, thereby making Staten Island a viable option as a commuter neighbourhood. A wave of real estate development occurred in response to the Bridge's opening, which included major attractions such as the Staten Island Mall and housing developments. The first major expressways were introduced in the 1970's and the region began to shed its rural character and grow into the suburban region that is part of the Island's reputation today. Land-uses that are considered in this study are presented in the map in Figure 1.

Fig. 1. Map of Staten Island with notable landmarks.

Though Staten Island has undergone significant developed throughout the second half of the 20th century, FKL has gained a position of prominence in the Island's physical landscape and notoriety. The landfill opened in an age when the City of New York was only beginning to understand the challenges of waste management for a sizeable population. Great Kills Landfill, the predecessor of Freshkills located on the eastern coast of Staten Island, was scheduled to close by 1948. In search of an effective solution to the City's growing garbage concern, the City of New York looked towards another 'wasteland' known as Freshkills. The 1946 Annual Report of the Department of Sanitation (DSNY) justifies the selection of the to-be FKL site: "The area to be reclaimed for park purposes consists of 1500 acres and should provide marine unloading disposal facilities for at least 10 years to come" (DSNY, 1946).

In 1947, Robert Moses opened Freshkills on a pledge that the landfill would be in operations for only three years. And after closure, a new expressway would be built on the landfill site (Purnick, 2002). In the first 8 months of operations in 1948, Freshkills accepted 15% of the City's waste volume, promptly increased to 28% in year 2 and stabilized at 33% in year 3, which surpasses the 18% and 21% share of waste that Great Kills accepted in 1946 and 1947, respectively. In 1951, operations at Freshkills were extended by city officials for an additional 15 to 20 years. According to the DSNY Commissioner in the 1951 Annual Report, the extension was allowed in order to "reclaim about 2,600 acres of wasteland for park and other useful purposes." In 1967, Sanitation Commissioner Samuel Kearing Jr. warned that Freshkills would reach capacity by 1977 (Bird, 1967); however, in 1970, the Department of City Planning advocated for 'mounding' of garbage such that capacity could be extended to 1986 (Burks, 1970). By 1989, mounding operations had been implemented and the landfill was projected to grow to a height of 505 feet by 2005 (Severo, 1989).

Figure 2 plots the annual unloaded at Freshkills between 1948 and 2001. Tonnage gradually increased until the late 1980's. However, this increase was only temporary due to the implementation of number of waste reduction and education programs, recycling programs, new avenues of waste disposal, and updated landfilling practices. Starting in the early 1990's, various measures were implemented to remediate and manage environmental standards. The two smaller sites at FKL (sections 2/8 and 3/4) were closed and completed closure construction by 1998 (DSNY 2008). The two larger sections, section 6/7 and section 1/9, closed in 1999 and 2001, respectively. .

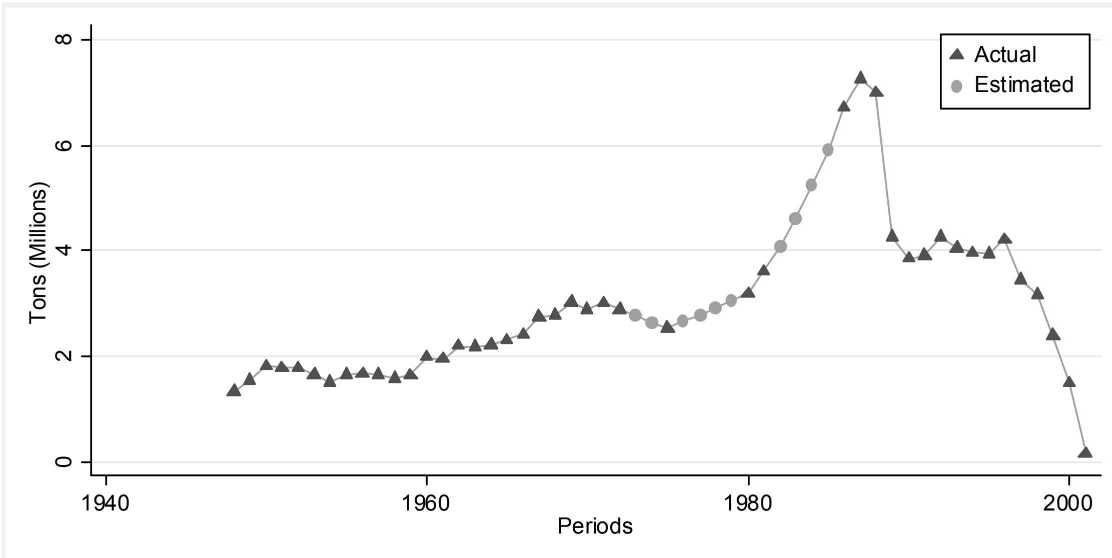

Fig.2. Millions tons of garbage received between 1948 and 2001. Crosshairs represent data interpolated from actual data (circles). Data are obtained mostly from DSNY and from New York Times articles.

In response to public opinion and changing environmental standards, New York Governor George Pataki signed an emergency order in 1996 to close Freshkills Landfill by December 31, 2001 (NYSDEC, 2001). While no definitive plan was in place to handle the diverted garbage, the City of New York began to rely on exportation of garbage out of the city as landfill operations phased out (DSNY, 2000). Freshkills had already undergone shutdowns of two of four sections in the early 1990's, but the larger sections (Section 1/9 and Section 6/7) continued filling operations into 1999 and 2001 respectively. By March 22, 2001, the last barge load of garbage arrived at the site. Since ending filling operations, the NYC Parks Department along with a number of other city agencies has guided the closure process. Each of the four landfill sections are in the process of being "closed" by impermeable material, retrofitted with additional gas collection system, and monitored for environmental concerns. Within 30 years' time, the Freshkills landfill will be one of the City's largest parks at three times the size of Central Park (NYC Parks Department, 2009).

3. Literature Review

At the forefront of methods used to evaluate these impacts is the hedonic price method developed in Rosen (1974), which suggests that the price of a competitive market good can be disaggregated into the values of its characteristics. For example, the price of a house can be attributed to the number of rooms, number of bathrooms, fireplace as well as neighbourhood characteristics. In environmental economic analysis, this is an especially potent tool as a properly specified hedonic model is a unique tool in isolating social value for environment externalities.

The hedonic literature on undesirable land use covers a variety of areas, including Superfund sites, power plants, production centres and landfills (see Boyle and Kiel (2001) for a detailed survey of studies). In particular, the landfill literature has yielded a number of insights into the impact of landfills:

- *Size does matter*. Lim and Missios (2007) find that property values around a landfill that received greater waste volumes experienced a larger negative impact than a smaller landfill. This may suggest that intensity and magnitude matters.
- *Ending filling operations may or may not have any impact*. Hite et al. (2001) find that closure of a landfill does not necessarily cause price recovery though the analysis does not provide evidence of sample comparability and is partially a post-intervention only analysis, whereas Kinnaman (2009) finds some evidence of price recovery after closure, but results are not statistically significant. In the case of a smelting facility in Dallas, McCluskey and Rausser (2003) find evidence that long term stigma may exist in a limited area around the site despite remediation though Dale et al. (1999) find evidence of recovery for the same smelter.

In examining a selection of landfill studies utilizing the hedonic method, as seen below in Table 1, one may notice that the housing distance-price gradient varies 1.1% per mile to 34% per mile.

Table 1. Selection of Previous Landfill-Specific Studies by House Price Impact per Mile, organized by year of publication

Article	Disamenity	Price Gradient		Period	Location	Sample
Thayer et *al*., 1992	Air Quality, Waste Site	1.10%	Per mile	1985-86	Baltimore, MD	N=2,323
Reichert et *al*., 1992	Landfill	3.0 - 7.3%	Per Mile	1985-89	Cleveland, OH	N=573
Nelson et *al*., 1997	Landfill	2.64% - 8.43%	per mile	1977-88	Eden Prarie, MN	N=644
Bouvier *et al.,* 2000	Landfills(multi)	6.27%	per mile	1992-95	Central Massachusetts	N=4767
Lim and Missios , 2007	Large Landfill Small Landfill	3.65% 2.21%	per mile	1987-91	Toronto, ON	N~1470
Kinnaman, 2009	Landfill (single)	34%	per mile	1957-95	Lewisburg, PA	N~1,076

Despite an established tradition of hedonic analyses, the literature has not systematically examined pre-post landfill impacts or considered the influence of maturation on model estimates. Testing for maturation is important to ensure that the underlying sample used for analysis is comparable for pre- and post-intervention periods. With this gap in mind, this research focuses on ensuring that the inference minimizes maturation signals while identifying clear closure-operation ending signals.

4. Methodological Approach

4.1. Hedonic Theory

As this research is grounded in a familiar tradition of hedonic methods as developed in Rosen (1974), a simple systematic analytical framework is developed We assume that individuals follow the utility function *U*:

$$U = U(c, x) \qquad (1)$$

Where *x* is a bundle of house characteristics such that $x = (x_1, x_2, \ldots, x_n)$ captures house-specific attributes, spatial and neighbourhood attributes, and environmental characteristics; and *c* is a composite good. Utility maximizing behaviour is guided by the budget constraint:

$$Y = c + p(x_i) \qquad (2)$$

Where *Y* represents income, $p(x_i)$ represents the hedonic price function of a bundle of attributes. Thus, the marginal willingness to pay p_{x_i} one additional unit of characteristic x_i is calculated following the first order condition:

$$p_{x_i} = \frac{\partial U / \partial x_i}{\partial U / \partial c_i} \qquad (3)$$

In applying this framework to an undesirable land-use, we may operationalize attitudes and preferences relating to the landfill in terms of distance. The fundamental assumption employed in this research is that housing prices may rise with distance away from a landfill following the distance-price gradient, and the gradient diminishes with ending landfill operations and remediation. As the distance-price gradient is a latent quantity, the hedonic framework must be well-specified to account for major factors that contribute to a house price before we may accurately assess the gradient. To do so, let *Y* represent the sales price of a housing unit and *X* represents a vector of housing and neighbourhood characteristics as generally specified as:

$$Y = X\beta + D_1\gamma + D_2\delta + P\psi + N\eta + T\tau + \varepsilon \qquad (4)$$

Where D_1 and D_2 are matrices of a distance variable segmented into pre-intervention and post-intervention periods, respectively; P is the intervention dummy; *N* represents amenity proximity dummies; *T* represents a regional housing price trend; and ε is a disturbance term. The remaining terms (β, γ, δ, η, τ,

ψ) are unknown parameters to be estimated. It is expected that the landfill impact on housing prices would reduce with the end of filling operations and remediation, thus the relationship for the coefficients of D_1 and D_2 would be $\delta < \gamma$.

4.2. End of Filling, Remediation or Maturation?

From a qualitative perspective, there are principally three potential factors that may contribute to the estimated landfill impact: end of filling operations, remediation and maturation. End of filling refers to the literal act of ending landfilling operations at the Freshkills site. Any influence attributable to ending operations would likely be manifested as a sharp discontinuity. Given the amount of garbage at the site, it is assumed here that it is not likely that the sight and smell of the landfill can be eliminated instantaneously without extensive remediation and management. Remediation refers to the process of cleaning up the landfill site for future use. Graphically, remediation would be a less distinct reduction in the distance coefficient—possibly a gradual curve or an S-survey. Lastly, maturation refers to 'natural' and 'cyclical' changes in housing characteristics over time. These shifts in the characteristics may induce the price-distance gradient estimates to artificially diverge.

Similar to threshold testing in a regression discontinuity design, the impact of operations can be tested by estimating a series of models that vary the regression time interval. The window tests facilitate the search for the earliest distinguishable change in impacts. To do so, hedonic models are estimated by systematically widening the window by 120 days up to 1440 days before and after the landfill closure in which the official date of the end of operations is March 22, 2001. In order to identify a representative time interval in which maturation is minimized and the joint remediation-operation ending effect is maximized, the following factors need to be determined:

- Maturation Check: The underlying covariate distributions are comparable; and
- Landfill Impact Reduction Check: The Pre-Post Distance coefficients need to be significantly different from one another.

The first factors utilizes a Mann–Whitney–Wilcoxon rank-sum test, which is a nonparametric alternative to the two sample t-test, and a simple Chi-square test for categorical or binary variables to test if covariates are similar before and after the intervention for each of the time intervals. It is expected that the sample will exhibit divergence in the larger time intervals and similarity in smaller time intervals. A matured cell is defined as a covariate-time interval cell with a rank-sum p-value less than 0.05. The maturation level, which is the degree to which covariates diverge, is approximated by the median rank-sum p-value of each period as one may be able to infer how many values diverge from the middle value.

For the second factor, the pre-intervention and post-intervention distance coefficients are estimated using a hedonic equation. Then, linear hypothesis tests are utilized to determine if the values are statistically different from one another. Under the null hypothesis that the coefficients are equal, a p-value under 0.05 would be interpreted as an approximate minimum necessary value in order to reject of the null and infer that the segmented coefficients exhibit a distinguishable reduction in the impact.

The first time window that satisfies the linear hypothesis test condition shall be used as the relevant period for statistical inference while paying careful to the degree of maturation.

5. DATA

Publically available housing sales data for both pre-intervention and post-intervention periods was not available due to city government confidentiality policies. Thus, private sources were consulted. The Staten Island Board of Realtors provided all sales within their network between 1997 and 2010 within a 2-mile radius of Freshkills. The data was first cleaned for repeat observations and incomplete records, which include units listed without a bedroom and/or bathroom. Furthermore, only single family homes were considered due to the number of observations available as well as the general standard to study single family homes due to lesser theoretical complications. Lastly, the sample was restricted to observations within 1,440 days of the end of filling operations to ensure time period symmetry for the time window testing around the date of intervention.

Observations were then geocoded to the New York City Department of Finance tax lot file. A series of geo-processes were performed to obtain house-level measures of distance to neighbourhood landmarks such as parks and railroad access; Census block and block group measures of ethnic composition, population density, income and travel time to work were combined as approximation of socioeconomic levels in various neighbourhoods; and a housing price index representative for the New York, New Jersey and Pennsylvania area was included to account for greater regional level trends in the housing market. Table 2 below provides an overview of variables utilized in the analysis.

Table 2. Model Variables

Variable	Description	Source
Housing Sales Variables		
Sales Price	Final sales price on housing unit	Staten Island Board of Realtors (SIBOR)
Bedrooms	Number of bedrooms in unit	
Baths	Number of bathrooms in unit	
House Class	3 Classes of Single Family Homes: Attached, Detached, and Semi-detached	
Property Dimensions	Dimensions of tax lot: length and depth	MapPLUTO/NYC Department of Finance
Floors	Number of floors in each structure	
Age of Structure	Age of structure (year of sale minus year of	

Variable	Description	Source
	construction)	
Socioeconomic Factors		
Per cent White	Proportion of Census Block Group population that identifies as 'White'	2000 US Census
Time to Work	Time to work	
Population Density	Total population in Census Block divided by total area of Census Block	
Income level	Median income of Census Block Group	
Neighbourhood Factors		
Proximity to Bus Stops	Within 0.6 mile of a bus stop	Metropolitan Transit Authority
Proximity to SIRR	Within 1 mile of a Staten Island Rail Road station	
Proximity to Parks	Within 0.2 mile of parks	New York City Department of City Planning
Proximity to Schools	Within 0.5 mile of a school	
Proximity to Industrial Land-Use	Within 0.3 mile of industrial land-use	
Distance to Freshkills	Distance from housing unit to landfill boundary	
Macroeconomic Factors		
Pre-intervention Dummy	Dummy for pre-intervention period	NA
Housing Price Index	Regional housing price index for New York, New Jersey and Pennsylvania	US Federal Housing Finance Agency

In previous hedonic research, factors that have been utilized in previous hedonic research include distance to parks and green space (considered in Hite et *al.*, 2001), malls (Dale et *al.*, 1999), transportation access and innovation (Ready and Abdalla, 2005) and a multiple local disamenities (Thayer et *al.*, 1992). Neighbourhood amenities in Staten Island include Staten Island Railroad, the Greenbelt park region, as well as price resistance factors such as industrial land uses. Cartesian distances were then measured between each housing unit and the boundary edge of each amenity. Proximity dummies were then constructed for each of the neighbourhood amenities and were systematically tested at one-twentieth mile intervals. It was found that variables representing proximity to parks, railroad stations, bus stops, schools and industry were the most appropriate due to statistical fitness.

6. RESULTS

6.1. Checking for maturation

Table 3 below presents non-parametric Wilcoxon-Mann-Whitney rank-sum test comparing continuous variables and chi-square tests for categorical variables for various 120 day windows. For the most part, structural and proximity characteristics of pre-intervention and post-intervention windows are not statistically different for periods immediately around the end of filling operations. However, beyond the +/-600 day period, the rate of rejection of the null hypothesis is consistent for certain variables and the proportion is pronounced.

Table 3. P-values for rank-sum tests and chi-squared comparing pre-post data (bold denotes p-values under 0.05)[1]

Variable	120	240	360	480	600	720	840	960	1080	1200	1320	1440
Bedrooms	0.98	0.21	0.13	0.16	0.24	0.19	0.73	0.51	0.30	0.31	0.27	0.08
Bathrooms	0.41	0.17	0.19	0.05	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Number of floors	0.49	0.43	0.63	0.36	0.25	0.17	**0.05**	0.08	**0.02**	**0.00**	**0.00**	**0.00**
Log(Length of Property)	0.64	0.81	0.93	0.89	0.92	0.67	0.78	0.59	0.49	0.28	0.20	0.08
Log(Depth of Property)	0.90	0.70	0.92	0.72	0.66	0.77	0.61	0.37	0.08	**0.05**	**0.02**	**0.01**
Log(Age of Structure)	0.86	0.50	0.08	**0.04**	0.31	0.58	0.39	0.07	0.06	0.16	**0.04**	**0.03**
Log(Median Income)	0.67	0.61	0.24	0.61	0.23	0.10	**0.03**	**0.03**	**0.01**	**0.00**	**0.00**	**0.00**
Log(Population Density)	**0.01**	0.45	0.55	0.64	0.20	0.05	**0.01**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**
Log(Time to Work)	0.78	0.67	0.22	0.10	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Ethnicity (% White)	0.12	0.50	0.61	0.20	0.06	0.12	0.10	0.24	0.30	0.39	0.75	0.91
Housing Classes	0.20	0.77	0.64	0.54	0.51	0.28	0.35	0.40	**0.05**	**0.00**	**0.00**	**0.00**
Proximity to Industry	**0.00**	0.06	0.34	0.95	0.87	0.55	0.87	0.54	0.31	0.20	0.29	0.52
Proximity to Parks	0.81	0.80	0.32	0.35	0.12	0.18	0.52	0.73	0.56	0.14	0.13	0.05
Proximity to SIRR	**0.03**	0.38	0.64	0.97	0.50	0.42	0.30	0.40	0.44	0.67	0.51	0.30
Proximity Bus	0.28	0.44	0.61	0.31	0.14	**0.04**	**0.03**	0.09	0.09	0.07	0.06	0.06
Proximity to Schools	0.40	0.26	0.10	0.19	0.06	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Housing Price Index	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distance(Freshkills)	0.91	0.37	0.40	0.26	0.15	0.31	0.22	0.13	**0.02**	**0.00**	**0.00**	**0.00**
Mean (P-value)	0.50	0.45	0.42	0.41	0.29	0.25	0.28	0.23	0.15	0.13	0.13	0.11
Median (P-value)	0.49	0.45	0.40	0.35	0.23	0.18	0.22	0.13	0.06	0.05	0.02	0.01
Proportion Rejected	18%	0%	0%	6%	12%	24%	41%	29%	47%	53%	59%	59%
Observation	538	1,272	1,827	2,486	3,184	3,783	4,403	5,159	5,844	6,458	7,191	7,795

To better display the changes in the rank-sum p-values over various regression windows, Figure 3 provides a box-whisker plot showing the spread of p-values. The vast majority of covariates are comparable before and after the intervention through +/- 1080 days. While it is challenging to develop a definitive criterion for maturation, it would be reasonable to select a period of analysis in which the samples are largely comparable across covariates; in this instance, a time window within +/-1080 days would be suitable

[1] As prices naturally rise over time and the underlying covariates are relative measures of socioeconomic conditions, the housing price index was not counted in the summary statistics of the pre-post hypothesis tests

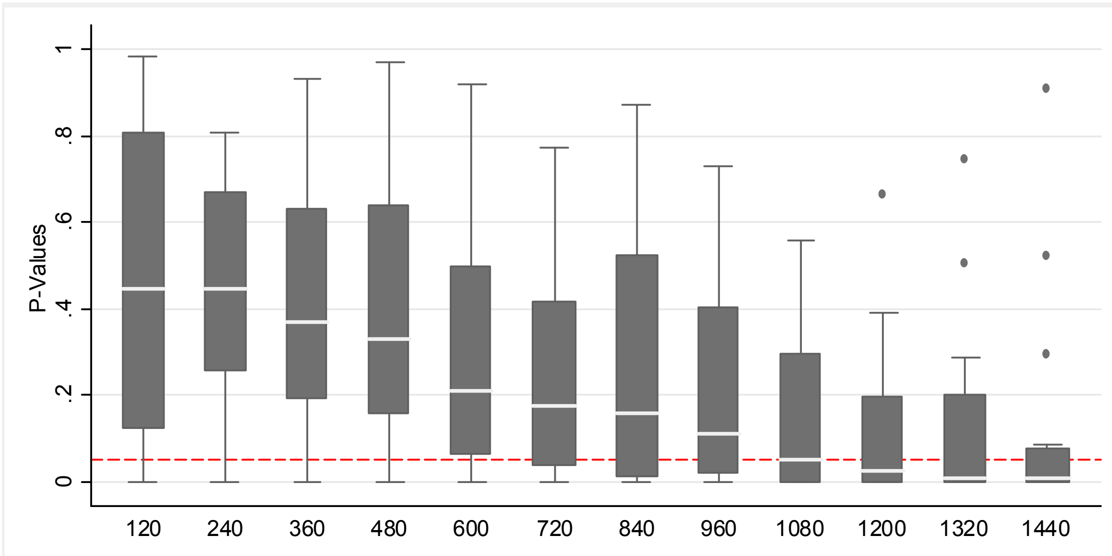

Fig.3. Box-whisker plot of spread of rank-sum p-values over regression windows. Red line indicates the p-value=0.05.

6.2. Hedonic Model Results

Initial modelling efforts considered segmenting covariates by pre- and post- intervention periods; however, the level of collinearity was much too great for reliable interpretation of coefficients. We thus must rely on the previously developed maturation tests to gauge the comparability and reliability of the sample. Hedonic models were estimated for each time window and Chow tests were calculated for each pair of segmented distance coefficients. For the most part, the coefficients exhibit the expected signs and are fairly stable. For complete model estimates, please see Appendix A.

Figure 4 plots the Chow tests for each time window in order to identify the period in which impact shifts are statistically meaningful. We can see that the p-values fall below 0.05 starting in the +/-600 day period (1.7 years) and the median maturation test is well-above the rejection threshold for that period. It is interesting to note that the Chow tests and the maturation tests fall towards the rejection threshold over time, possibly an indication that pre-post coefficients are increasingly statistically different due to lack of comparability. However, referring back to Table 3, the proportion of covariates that have matured is 12% or 2 covariates diverge at +/-600 days, thus we may be fairly confident that the distance variable is measuring the landfill impact for that period.

The pre-post intervention coefficients for each time interval are graphed in Fig. 5. The landfill impact before the end of operations is on average 5.4% (Min =4.5%, Max=6.0%) and falls to an average 3.7% (Min=2.9%, Max=5.5%) in the post-intervention period, though noting that comparability of the pre-post samples diminishes with time. When analysing the coefficient trend over time, it is apparent that impact shifts in the post-intervention period show a consistent decreasing trend—the underlying effect of which may be difficult to discern between the environmental quality changes and statistical conditions inherent in the sample. For the +/- 600 day window, the distance-price gradient has fallen from a large 5.9% mile per mile to 3.9% rise per mile. This shift in average impact is unlikely attributable to the end of filling operations alone in the short run; however, an impact would be more likely observed when operation ending is coupled with on-going closure construction efforts. In this case, we can see that the pre-closure gradient had not fallen; perhaps indicating that closure of three of four of the landfill's sections by the intervention and commencement of capping was not sufficient in reducing landfill impacts while the fourth section was still undergoing filling operations.

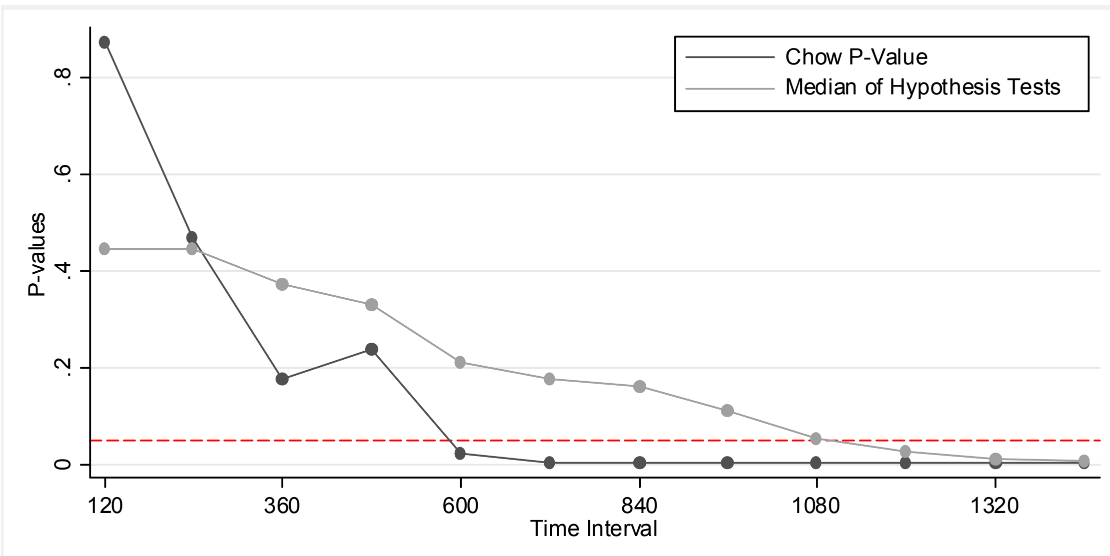

Fig. 4. Chow Test P-values and hypothesis test p-values. Red line indicates the p-value=0.05.

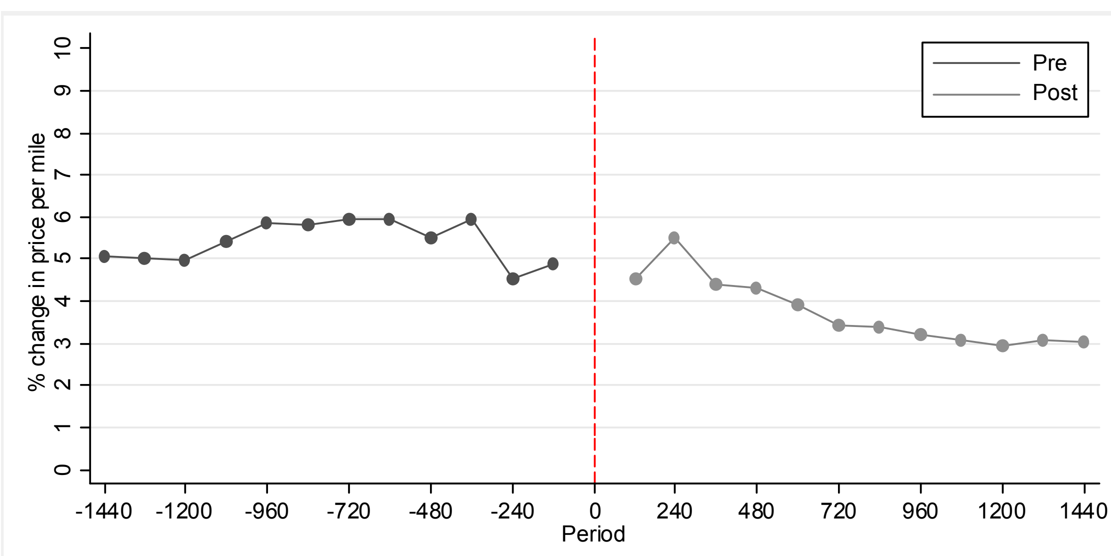

Fig. 5. Distance Coefficients by Pre-Post Intervention Intervals

7. CONCLUSION

Using simple but systematic methods for determining the level of maturation or comparability, this research finds that the end of operations and closure construction of Freshkills Landfill has likely reduced the impact on housing prices from 5.9% increase in prices per mile from the landfill to 3.9% per mile. As the Chow tests indicate that pre-post distance coefficients are significant at the 5% level starting at +/-600 days, it may be inferred that the time lagged observed price recovery may be associated with a combination of remediation and the end of filling operations rather than the end of operations exclusively while noting that approximately 12% of covariates were divergent.

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APPENDIX A: REGRESSION RESULTS

Period	120	240	360	480	600	720	840	960	1080	1200	1320	1440
Observation	538	1,272	1,827	2,486	3,184	3,783	4,403	5,159	5,844	6,458	7,191	7,795
RMSE	0.140	0.140	0.140	0.143	0.144	0.145	0.149	0.149	0.149	0.151	0.150	0.150
Adj. R-Squared	0.792	0.792	0.789	0.790	0.799	0.803	0.800	0.806	0.809	0.810	0.818	0.821
Constant	10.207***	9.530***	8.995***	9.200***	8.979***	8.699***	8.645***	8.738***	8.965***	8.968***	9.066***	9.051***
	(1.061)	(0.590)	(0.473)	(0.400)	(0.361)	(0.326)	(0.312)	(0.292)	(0.276)	(0.265)	(0.249)	(0.240)
Bedrooms	0.082***	0.088***	0.095***	0.096***	0.098***	0.100***	0.099***	0.098***	0.096***	0.094***	0.094***	0.097***
	(0.010)	(0.007)	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Bathrooms	0.057***	0.042***	0.043***	0.045***	0.049***	0.055***	0.058***	0.060***	0.060***	0.058***	0.058***	0.058***
	(0.010)	(0.007)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Number of floors	0.040***	0.043***	0.046***	0.046***	0.047***	0.044***	0.044***	0.044***	0.045***	0.046***	0.047***	0.046***
	(0.014)	(0.009)	(0.008)	(0.007)	(0.006)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Log(Length of Property)	0.204***	0.236***	0.237***	0.270***	0.267***	0.246***	0.232***	0.242***	0.237***	0.244***	0.243***	0.242***
	(0.034)	(0.023)	(0.019)	(0.016)	(0.014)	(0.012)	(0.012)	(0.011)	(0.010)	(0.010)	(0.009)	(0.009)
Log(Depth of Property)	0.282***	0.234***	0.229***	0.240***	0.237***	0.219***	0.216***	0.221***	0.220***	0.221***	0.225***	0.222***
	(0.033)	(0.022)	(0.018)	(0.015)	(0.013)	(0.012)	(0.011)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)
Age of Structure	-0.079***	-0.068***	-0.061***	-0.063***	-0.058***	-0.056***	-0.057***	-0.056***	-0.055***	-0.053***	-0.054***	-0.053***
	(0.009)	(0.006)	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Log(Median Income)	0.029	0.048	0.083**	0.078***	0.105***	0.130***	0.153***	0.133***	0.124***	0.117***	0.113***	0.114***
	(0.061)	(0.042)	(0.035)	(0.030)	(0.027)	(0.024)	(0.023)	(0.021)	(0.020)	(0.019)	(0.018)	(0.018)
Log(Population Density)	0.001	-0.002	-0.000	-0.000	-0.002	-0.003	-0.005*	-0.006**	-0.007**	-0.006**	-0.005**	-0.006***
	(0.008)	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Log(Time to Work)	-0.315***	-0.263***	-0.252***	-0.290***	-0.289***	-0.274***	-0.291***	-0.272***	-0.290***	-0.263***	-0.271***	-0.263***
	(0.086)	(0.057)	(0.047)	(0.041)	(0.037)	(0.034)	(0.033)	(0.030)	(0.029)	(0.027)	(0.026)	(0.025)
Ethnicity (% White)	0.461***	0.414***	0.429***	0.395***	0.371***	0.343***	0.319***	0.336***	0.324***	0.315***	0.307***	0.305***
	(0.069)	(0.046)	(0.038)	(0.033)	(0.029)	(0.027)	(0.026)	(0.024)	(0.022)	(0.021)	(0.020)	(0.019)
Dummy(Class 1)	-	-	-	-	-	-	-	-	-	-	-	-
Dummy(Class 2)	0.396***	0.373***	0.354***	0.329***	0.328***	0.334***	0.337***	0.333***	0.337***	0.338***	0.336***	0.331***
	(0.028)	(0.018)	(0.015)	(0.013)	(0.011)	(0.010)	(0.010)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)
Dummy(Class 3)	0.182***	0.199***	0.189***	0.178***	0.171***	0.167***	0.162***	0.161***	0.162***	0.166***	0.163***	0.159***
	(0.018)	(0.012)	(0.010)	(0.009)	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
Proximity to Industry	0.005	0.004	0.009	0.007	0.009	0.009	0.010*	0.007	0.006	0.003	0.003	0.005
	(0.017)	(0.011)	(0.009)	(0.008)	(0.007)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
Proximity to Parks	0.012	0.005	0.003	0.003	0.001	-0.004	-0.006	-0.009	-0.006	-0.006	-0.009*	-0.008*
	(0.018)	(0.011)	(0.009)	(0.008)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.004)
Proximity to SIRR	0.055***	0.047***	0.038***	0.051***	0.053***	0.058***	0.061***	0.059***	0.060***	0.061***	0.062***	0.062***
	(0.017)	(0.011)	(0.009)	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
Proximity Bus	0.009	-0.008	-0.006	-0.003	-0.005	-0.010*	-0.012**	-0.009*	-0.011**	-0.010**	-0.011**	-0.011***
	(0.015)	(0.010)	(0.008)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
Proximity to Schools	0.020	0.044***	0.041***	0.039***	0.044***	0.045***	0.041***	0.038***	0.037***	0.036***	0.035***	0.034***
	(0.015)	(0.010)	(0.008)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)

APPENDIX A: REGRESSION RESULTS

Period	120	240	360	480	600	720	840	960	1080	1200	1320	1440
Housing Price Trend	0.004	0.008***	0.008***	0.008***	0.007***	0.008***	0.007***	0.007***	0.007***	0.007***	0.007***	0.006***
	(0.006)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distance(Pre-FKL Closure)	0.049***	0.045***	0.059***	0.055***	0.059***	0.060***	0.058***	0.058***	0.054***	0.050***	0.050***	0.051***
	(0.018)	(0.011)	(0.009)	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
Distance(Post-FKL Closure)	0.045***	0.055***	0.044***	0.043***	0.039***	0.034***	0.034***	0.032***	0.031***	0.029***	0.031***	0.030***
	(0.017)	(0.010)	(0.009)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
Dummy(Pre-March 22, 2001)	-0.021	-0.004	-0.028	-0.036**	-0.051***	-0.050***	-0.054***	-0.060***	-0.066***	-0.076***	-0.084***	-0.094***
	(0.033)	(0.022)	(0.018)	(0.015)	(0.013)	(0.012)	(0.011)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1