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Abstract

This study investigates the spatial concentration of waste landfill sites over two decades. Using a unique dataset of 2,164 industrial-waste landfill sites from 1992 to 2012, we find a persistent spatial concentration of sites managed by private companies. The empirical results show that the economic factors and the existence of other waste-related facilities have a positive effect on the location of private landfill sites. Interestingly, this relationship was fairly stable for 20 years despite a significant decline in the number of sites in operation. The results suggest the difficulty in addressing NIMBY "not in my backyard" issues without public intervention.

Keywords: Waste landfill site, Industrial waste, Spatial econometrics, NIMBY, Japan

JEL Classification D72, Q53, R39

1. Introduction

Determining locations of unwanted facilities often causes disputes. A typical example is a solid waste landfill site that local communities are reluctant to accept even though they understand the importance of such facilities for society in general. For every big city, finding a good location for a waste landfill is a challenge. New York City, where available land for waste disposal is in short supply, transports much of its municipal solid waste by truck, train, and barge to landfill sites as far as 600 miles away (Galka, 2016). The situation is also serious in rapidly growing economies whose amount of waste is dramatically increasing. Cities in China are running out of suitable places for landfills and are turning to incinerators, although their constructions also face opposition by and protests from local residents (The Economist, 2015).

As a country with high population density and scarce land resources, Japan provides an excellent setting for studying the NIMBY (not in my backyard) issue. In 2012, 2,164 industrial-waste landfill sites operated in Japan. As is subsequently shown in this paper, only 25% of Japanese municipalities have locations for these sites. The concentration of landfill sites in one place might worsen NIMBY issues. For example, Sasao (2004) pointed out that a sense of unfairness at having to treat waste generated by other communities is a major reason for residents' opposition to NIMBY facilities. Is there any place that has a geographical advantage regarding the location of an unwanted facility dealing with "bads"? What are the determinants of the spatial concentration of landfill sites? Although the number of landfill sites in Japan has decreased given a steady increase in recycling, has the spatial distribution of sites changed over time? To answer these questions, a detailed investigation into landfill site locations over a long period is needed.

This study aims to investigate the spatial distribution of landfill sites for industrial waste. Using a unique dataset of 2,164 landfill sites from 1992 to 2012 in Japan, we analyze the changes in the spatial concentrations and factors that affect their locations. The first contribution of this study is to explore the spatial distribution of landfill sites over time. Because the long-term location data on industrial-waste has landfill sites have been rarely available, as far as the authors are aware, few studies have examined the factors that affect the location of waste landfill sites.

[i] We overcome this unavailability by requesting the disclosure of data from all Japanese local governments that are in charge of site location licensing. As a result, we collected all of location data on 2,164 private and public industrial-waste landfill sites that operated from 1992 to 2012.[ii]

The second contribution of this study is to show how market forces work regarding the location of NIMBY facilities. In general, location as a result of market equilibrium differs from that of political equilibrium. Private firms pursue profit maximization or cost minimization when locating their plants and facilities, whereas governments focus on social welfare or political support from the industrial sector and the local community. Therefore, differences likely exist between private and public NIMBY facilities regarding the factors that affect their location. Previous studies have investigated the location decision for unwanted facilities with a focus on the political equilibrium (e.g., Feinerman et al., 2004; Aldrich, 2008; and Laurian and Funderburg, 2014). Feinerman et al. (2004) focused on the political aspects of the siting process to resolve conflicts with residents. Aldrich (2008) explored the relationship between local civil society and the location of controversial facilities, such as nuclear power plants, in Japan. He found that the greater the concentration of local civil society, the less likely it was that state-planned projects would be completed. Laurian and Funderburg (2014) analyzed the determinants of the location of public incinerators in France from the viewpoint of environmental justice. Although these studies were related to public site selection under a political equilibrium, little empirical research has been done on the location of NIMBY facilities managed by private companies.

This paper also relates to studies on the impact of environmental regulation on the location of a polluting industry. For example, Stafford (2000) examined the impact of environmental regulations on the location decisions of hazardous-waste management firms. The result indicates that state enforcement of environmental regulations affects the cost of providing waste management and, thereby, serves as an important driver for location decisions of waste management firms. In the context of the EU pig industry location, Mulatu and Wossink (2014) found that highly polluting sectors of the industry are attracted to jurisdictions with lax environmental regulations. In contrast to these studies, our study explicitly considers the impact of environmental regulation on the spatial correlations and changes in the concentration of economic activities that potentially result in negative externalities to local communities.

Our empirical results show that a spatial concentration of landfill sites existed in Japan from 1992 to 2012. Economic factors, such as land price, industrial-waste volume, and highway infrastructure, play a significant role in the location patterns of landfill sites managed by private companies. Interestingly, this relationship has been fairly stable for 20 years despite a significant decline in the number of operating landfill sites. In contrast, policy and environmental factors were found to play a modest role in the location of private landfill sites. These results suggest that market forces strongly affect the concentration of landfill sites.

The remainder of this article is organized as follows. The next section describes the background of industrial-waste management in Japan. Section 3 explains the method used to estimate spatial dependence. Section 4 explains the study's empirical strategy and the model's specification and data, and Section 5 provides the results of the analysis on the spatial concentration of landfill sites. Finally, Section 6 concludes and discusses policy implications.

2. Background

In Japan, all wastes are classified as "industrial waste" or "municipal solid waste," and separate regulations are applied under the Waste Management Law of 1970. After considerable separation for recycling or incineration, industrial waste is generally disposed of in landfill sites managed by private waste-management companies, whereas municipal solid waste is disposed of in sites managed by local municipalities.[iii] Thus, the management of industrial waste is based on market mechanisms.

Under competitive market conditions, waste-management companies consider profit maximization when making location decisions regarding their sites and do not sufficiently consider inequalities caused by the geographical concentration of their sites. Therefore, the location of industrial-waste landfill sites might lead to the uneven distribution of unwanted facilities for a long time. Examining the cross-sectional 2012 data on Japanese municipalities, Ishimura and Takeuchi (2017) found that a spatial concentration of industrial-waste landfill sites exists in areas with other waste-related facilities. Previous studies also explored how the NIMBY issue can be alleviated or mitigated (Sasao, 2004; Frey and Oberholzer-Gee, 1996; Sakai, 2012). For example, Sasao (2004) indicated that the sense of unfairness at having to treat waste generated by other communities is a major reason for residents' opposition to NIMBY facilities. Therefore, the concentration of landfill sites in one place might severely worsen the NIMBY issue and make the construction of landfill sites more difficult.

The Japanese Ministry of Environment (MOE) has taken measures to mitigate strong opposition from local residents regarding the construction of landfill sites and to maintain sufficient capacity for waste landfill. Since 1992, the MOE has required companies managing landfill sites to obtain permission from the prefectural government before commencing construction and closing sites. To obtain such permission, companies are required to follow environmental assessment procedures, and the sites should be constructed in accordance with the technical standards for treatment facilities and site structures. Although prefectural governments are responsible for issuing the permission, they approve the construction as long as the company's application fulfills the conditions required by law. Thus, prefectural governments do not have the authority to limit either the number of industrial landfill sites or their location within their administrative boundaries.

In 1997, the MOE reinforced regulations for the construction and management of industrial-waste landfill sites by revising the Waste Management Law. This revision included establishing a maintenance reserve fund, restricting permissions to construct and close landfill sites and developing standards for facility structures and operations. In addition, since 1998, the Waste Management Law has required landfill site constructors to investigate the effect of noise, stench, water, and soil pollution on the living environment. Furthermore, since 1999, the Environmental Impact Assessment Law has required waste-management companies to submit environmental assessment reports, which include public opinion on the matter, when applying for prefectural permission to construct a landfill site. Tightening the regulations might have increased the cost to operate and manage landfill sites and has led to a decrease in the number of operating landfill sites. In fact, the number of operating landfill sites has continued to decrease since 1997.

In addition to federal regulations, the local government can also affect the location decision of waste facilities. On the basis of U.S. municipal data, Stafford (2000) indicated that the state's enforcement of environmental regulations affects the cost of providing waste management and, thereby, serves as an important driver for location decisions made by hazardous-waste management firms. Although local governments' regulation and enforcement are relatively homogeneous, the introduction of an industrial-waste tax and shipment restrictions by some prefectures might have affected the location decision by causing prefectures with stricter regulations to be avoided. After Mie prefecture first introduced an industrial-waste tax in 2002, another 27 of Japan's 47 prefectures have enforced similar industrial-waste taxes, including landfill taxes and incineration taxes. Sasao (2014a) indicated that industrial waste taxes in Japan have minimal effects on reducing the amount of waste for landfill sites. Another local policy instrument is shipment restrictions on industrial waste, which is enforced in 33 prefectures. Sasao (2014b) showed that waste-trade restrictions in the destination prefecture decrease the inflow of waste to landfill sites in these prefectures. The introduction of an industrial-waste tax and shipment restrictions can indirectly affect the location of a landfill site by decreasing the demand for waste landfill services in those areas and shifting the site location to another area.

Stricter regulations on landfill sites might make the market for waste landfills more competitive. The tightening of environmental regulations increases the cost of operating and managing landfill sites. In addition, because of the development of recycling used materials, the amount of industrial waste disposed in landfill sites has decreased by 85% during these two decades. As a result, the number of landfill sites in operation has been decreasing. At the same time, infrastructure developments have also impacted landfill site locations. The total length of the highway infrastructure in Japan has increased by 60% during the last two decades. Highway infrastructure development decreases transport and time costs and eventually facilitates the transfer of waste to landfill sites with the least expensive disposal fees. In fact, the share of industrial waste transferred to landfill sites in other prefectures has increased from 7% in 2000 to 23% in 2012.[iv] These factors together have likely affected the distribution of sites and have resulted in a higher concentration in areas with lower operation costs and a higher-than-ever demand for waste landfills.

3. Spatial Dependency in Landfill Site Location

In this section, we investigate the spatial concentration of industrial-waste landfill sites. To test for possible spatial dependency, we estimate Moran's I statistic (Anselin, 1988, 1995), which is defined as follows:

$$Moran's\ I = \frac{N}{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}} \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{N}(x_i-\bar{x})^2},$$

where x_i is the number of industrial-waste landfill sites per resident in municipality i, $(x_i - \bar{x})$ is the deviation of attribute x for municipality i, w_{ij} is the spatial weight between municipality i and j, N equals the total number of municipalities, and $\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}$ is the aggregate of all spatial weights. The details of the location data on industrial-waste landfill sites are described in Section 4. In general, a Moran's I value near +1.0 indicates clustering, an index value near –1.0 indicates dispersion, and 0 indicates randomness. Additional terms are defined as follows:

$$w_{ij} = \frac{c_{ij}}{\sum_{i=1}^{N} c_{ij}} \qquad c_{ij}(i, j = 1,2, \dots, N),$$

where c_{ij} takes the value of 1 when municipality i and j are contiguous, and it takes a value of 0 when two municipalities are not contiguous. The spatial weight matrix W is based on the actual neighboring relationship between municipalities using a queen-type contiguity.

The estimation results show that the Global Moran's I statistics are positive and statistically significant at the 1% level for each year from 1992 to 2012. For instance, the Global Moran's I statistic is 0.144 in 1992 and 0.202 in 2012. These results indicate that an agglomeration of waste landfill sites has existed in some areas during the two decades.

Moreover, we estimate the Getis–Ord Gi^* statistic (Getis and Ord 1992; Ord and Getis 1995) in order to detect local patterns of spatial association. The Getis–Ord Gi^* statistic is defined as follows:

$$G^* = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{i,j} x_i x_j}{\sum_{i=1}^{N}\sum_{j=1}^{N} x_i x_j}.$$

The G^* statistic calculated for each municipality is a Z score. A positive and larger Z score value indicates more intense clustering of high values. A negative and smaller Z score value indicates more intense clustering of low values. The specific test results and a description of the clusters for 1992 and 2012 are presented in Figures 1 and 2, respectively. As shown in these figures, we find that the G^* statistics tend to be high for municipalities in Hokkaido prefecture. This result is reasonable because Hokkaido is the prefecture with the largest livestock production in Japan, with many livestock farmers in particular in the southeastern area. According to Hokkaido Prefecture (2012), half of the total industrial waste in Hokkaido prefecture is composed of animal manure. Thus, the livestock sector supplies a large amount of waste that lead to higher demand for landfill. In addition, Hokkaido is the largest prefecture in terms of land area and has a sparse population. Therefore, more land is available for waste landfill than in other prefectures. The figures suggest that, during the study period, the landfill site cluster has moved toward the northwest from the southeast in Hokkaido prefecture.

4. Spatial Econometric Methodology

4.1 Model specifications

Following the analysis of the previous section, we estimate a spatial autoregressive tobit model (SAR tobit model) to incorporate the spatial dependence in a regression model and to investigate the regional characteristics that lead to higher landfill-site concentration. A SAR tobit model is defined as follows:

$$y_i^* = \beta_0 + \rho WX + X\beta + \varepsilon$$

$$y_i = \begin{cases} y_i^* & if\ y_i^* \geq 0 \\ 0 & if\ y_i < 0 \end{cases},$$

where y_i^* is the number of landfill sites managed by private companies for industrial waste per 10,000 residents in municipality i, which takes the value of 0 if no landfill site exists in the municipality; X is a vector of characteristics describing the site; W is the spatial weight matrix; and β and ρ are parameters. The negative values in vector y_i^* are set to 0 to reflect sample truncation at 0. The spatial interdependence induces a truncated multivariate normal distribution (TMVN) for the latent variable, which takes the following form:

$$y_i^* \sim TMVN(\mu, \Omega)$$

$$s.t. \mu = (I_n - \rho W)^{-1} X\beta$$

$$\text{and } \Omega = \sigma_\varepsilon^2 [(I_n - \rho W)'(I_n - \rho W)]^{-1},$$

subject to a vector of liner inequality restrictions $a \leq y^* \leq b$, where the truncation bounds depend on the observed values of y. To estimate the spatial tobit model, we apply the Bayesian strategy of the

Markov Chain Monte Carlo (MCMC) sampling method (LeSage 1999, 2000; LeSage and Pace 2009). LeSage (1997) suggested the estimation method for the spatial lag model (SLM) parameter by using the MCMC, which allows for a direct estimation of the influence of heteroskedasticity. In our estimation, the parameters are estimated using the Gibbs sampling method on the basis of 1,000 retained draws from a sample of 1,100.

We also investigate the OLS model without taking into account the spatial correlation, which is defined as follows:

$$y = \beta_0 + \rho WX + X\beta + \mu$$
$$\mu = \lambda W\mu + \varepsilon,$$

where ρ and λ are spatial autocorrelation parameters; *W* is the spatial weight matrix; and μ is the error term. Then, $\rho = \lambda = 0$ in the simple OLS based on the null hypothesis of no spatial correlation. If the dependent variable is spatially correlated, $\rho \neq 0, \lambda \neq 0$, and the OLS estimator leads to significant model misspecification and biased parameter estimates (Anselin, 1988; LeSage and Pace, 2009). Thus, we test the null of no spatial correlation in the OLS residual by using Moran's I, the Lagrange multiplier, and Robust Lagrange multiplier tests. Although Moran's I and the Lagrange multiplier test for both lags and errors under the null of no spatial correlation, the Robust Lagrange multiplier tests for lags and errors under the null of $\rho = 0$ and $\lambda = 0$ without restrictions on the values of ρ and λ.

4.2 Data and explanatory variables

The locations of industrial-waste landfill sites in Japan have not been made publicly available, even though the prefectural governments obtain this information through the construction permission process. We sent requests to all prefectural governments in Japan for information disclosure of the landfill sites after 1992, when the licensing system to construct, operate, and close landfill sites was initiated. As a result, we obtained information on location, operating years, type of waste, and type of site for 2,164 industrial-waste landfill sites (1,757 private landfill sites, 579 hazardous landfill sites, and 177 public landfill sites) that operated from 1992 to 2012. The number of operating private landfill sites is 1,071 for 1992 and 893 for 2012. The number of landfill sites increased from 1992 until 1998 and then decreased by 34% from 1999 to 2012. Figures 3 and 4 indicate the locations of the industrial-waste landfill sites in operation in 1992 and 2012. We find that 72% of Japanese municipalities in 1992 and 75% in 2012 had no industrial landfill sites.

These location data cover all 1,692 municipalities in Japan that share a border with at least one other municipality, and they are aggregated at the municipality level. Municipality-level data provide us with detailed information to investigate the location of private landfill sites by considering the characteristics of local communities that locate the landfill sites. To adequately analyze the concentration of landfill sites, prefectural-level data are too crude and do not reflect the geographical distribution and its determinants. For instance, prefectural-level data cannot distinguish between a case in which all landfill sites are concentrated in a few municipalities within a prefecture and a case in which these sites are distributed evenly across all municipalities, even though the total number of landfill sites in a prefecture remains the same. Moreover, long-term data enable us to investigate the changes in the spatial distribution of waste landfill sites. Because industrial-waste landfill sites operate for an average of 11 years, their locations might have changed considerably during our sample period (that is, 20 years). In fact, out of 893 private landfill sites that were operating in 2012, less than half (398 sites) have been operating since 1992.

We hypothesize that the following five factors influence the location of landfill sites.

Economic factor

The first factor is private costs and benefits for waste-management companies when locating landfill sites in particular municipalities. Fortenbery et al. (2013) suggested that input markets have a significant effect on the location of biodiesel refineries. A similar effect might affect the location of waste landfill sites. For industrial waste, the input for landfill sites is the waste generated by industrial activities. This study uses four variables for the economic factor: (1) the amount of industrial waste generated at the prefectural level, (2) the revenue from the local manufacturing sector's production measured at the municipal level, (3) the total length of the highway infrastructure measured at the prefectural level, and (4) the land price measured at the municipal level. The amount of industrial waste captures the supply of waste for landfills within the prefecture.[v] The total production revenue by the local manufacturing sector captures the demand for waste landfill in the municipality. The total length of the prefecture's highways reflects the amount of transportation infrastructure, and a greater length should be associated with lower transportation costs. The land price constitutes a significant part of the fixed cost when companies construct landfill sites.

Data on industrial-waste generation are drawn from the Survey on Industrial Waste Emissions and Landfill (Japanese Ministry of the Environment, respective years). Data on manufacturing production are drawn from the census of manufacturers (Japanese Ministry of Economy, Trade and Industry, respective years). Data on the total length of the highway infrastructure in each prefecture are drawn from the Annual Report of Road Statistics (Japanese Ministry of Land, Infrastructure, Transport and Tourism, respective years). We use the average land price in each municipality, which is reported in land-price investigations by prefectural governments. Land-price data for each year are derived from the Geographic Information Systems (GIS) database of the Geospatial Information Authority of Japan.

Existence of other waste-related facilities

The second factor is the existence of other waste-related facilities. To measure the impact of this factor, three variables are employed: the number of intermediate processing facilities for industrial waste per capita, the number of landfill sites for hazardous waste per capita, and a dummy variable for industrial-waste landfill sites managed by public-sector involvement. Intermediate processing facilities and hazardous-waste facilities are both unwanted land uses that typically face significant public opposition in their siting. Public opposition negatively affects site location for two reasons: (1) transaction costs become higher for waste-management companies to negotiate with inhabitants, and (2) opportunity costs also become higher as the construction and operation of a site are delayed. Thus, waste-management companies tend to locate landfill sites in areas in which construction is easier—that is, areas with an existing landfill site. Intermediate waste-processing facilities include incineration plants, recycling plants, crushing plants, and separation plants for industrial waste. This variable can also be interpreted as access to input markets because the output of these intermediate facilities is, ultimately, waste that requires a final landfill. For a waste-management company to find a suitable location for hazardous-waste facilities is difficult because even stronger opposition from residents than to an industrial-waste facility might exist. Thus, a higher number of other waste-related facilities per capita in a municipality is expected to increase the number of private landfill sites for industrial-waste per capita in that municipality. Data on intermediate processing facilities are derived from the Survey

Report on Administrative Organizations for Industrial Waste by the Japanese Ministry of the Environment. Location data for hazardous-waste landfill sites were collected through our survey.

In contrast to these two waste-related facilities, industrial-waste landfill sites with public-sector involvement are expected to reduce the concentration of private landfill sites within a municipality. To facilitate using landfills for waste, some prefectural and municipal governments play an active role in the construction of industrial-waste landfill sites. The main reason for this involvement is to reduce objections from residents that may arise out of distrust of private companies pursuing economic returns. In a municipality, we expect that landfill sites being operated by the public sector will lead to a lower number of such sites because they can substitute for landfill sites managed by private companies. The location data for these public industrial-waste landfill sites are also taken from the disclosure requests.

Environmental factor

The third factor is the environment. To obtain an allowance to begin construction, waste-management companies are required to follow environmental assessment procedures. Among the various aspects investigated during this process, we consider two representative factors that might strongly affect landfill site locations: the prefectural nature reserve and the amount of groundwater usage at the prefecture level. By including these variables, we can examine whether a site location is influenced by the consideration of the natural environment.

Data on nature reserves are based on prefectural nature conservation areas as of 1992 and 2012 (Japanese Ministry of Environment [vi]). Under the Japanese Nature Conservation Law, nature conservation areas are classified as wilderness areas, nature conservation areas, and prefectural nature conservation areas. Prefectural nature conservation areas are designated by prefectural governments, and regulations on land use in such areas are less strict than for the other two types of areas. The nature dummy variable takes a value of 1 if a prefectural nature conservation area exists in the municipality, and it takes a value of 0 otherwise. Data on groundwater usage are drawn from the Survey on the Usage of Groundwater for Agriculture in 1991 and 2011 (Japanese Ministry of Agriculture, and Fisheries, respective years).

Regional characteristics

The fourth factor considered is regional characteristics. These include the unemployment rate, population density, percentages of agricultural and manufacturing workers, the municipal financial stability index, and two dummy variables related to population size (municipalities with less than 10,000 people and those with more than 200,000 people). The unemployment rate captures the environmental justice aspect of locating waste-management facilities. Laurian and Funderburg (2014) found that towns in France with large, vulnerable populations are more likely to host waste-incineration facilities. The unemployment variable allows us to test the hypothesis that industrial-waste landfill sites might be spatially concentrated in municipalities with more disadvantaged populations. High population density is a simple measure of the NIMBY syndrome, indicating that many inhabitants who would oppose the construction and operation of a site potentially exist. Agricultural workers might fear that landfill sites will leak pollutants and damage their crops. Conversely, a higher ratio of manufacturing workers and a high municipal financial stability index value indicate greater economic activity, and a municipality that has such characteristics is more likely to support landfill site locations. Two dummy variables related to population are included to test whether industrial-waste landfill sites are located in rural, urban, or other areas. Thus, we use two dummy variables: (1) Rural area dummy (1 = municipality with less than a population of 10,000; 0 = others) and (2) Urban area dummy[vii] (1= municipality with a population of more than 200,000; 0 = others).

Unemployment, population density, percentages of agricultural and manufacturing workers, and population data are drawn from the 1990 and 2010 National Census (Japanese Ministry of Internal Affairs and Communications). The municipal financial stability index is drawn from the financial indicators of local governments for 1992 and 2012 (Japanese Ministry of Internal Affairs and Communications).

Policies

The last factor considered is the policy implemented by prefectural-level governments. In this study, we look in particular at the impact of industrial-waste taxation and waste-trade restrictions. Sasao (2014) examined the effects of these policy instruments on waste generation and transfer and found that industrial-waste taxes in Japan have minimal effects on the reduction of the amount of waste for landfill sites, whereas waste-trade restrictions in destination prefectures decrease the inflow of waste to their landfill sites. The introduction of an industrial-waste tax and waste-trade restrictions by some prefectural governments decreased the demand for waste-landfill services and might have affected location decisions by encouraging the avoidance of prefectures with stricter regulations. We use dummy variables to represent the introduction of an industrial-waste tax and waste-trade restrictions.[viii] Because the first introduction of an industrial-waste tax was in 2002, we include the industrial-waste tax variable only in the 2012 model.

Data for the industrial-waste tax are drawn from the 2011 survey report on the condition of local governments implementing an industrial-waste tax (Hiroshima Prefecture). The data for waste-trade restrictions are drawn from the survey report on the administration of industrial waste (Japan Leasing Association).

5. Results

To compare the factors that affect the location of waste landfill sites in 1992 and 2012, we estimate models that take the number of industrial-waste landfill sites per capita in each year as the dependent variable. Because of the high correlation between the amount of industrial waste and the length of the highway infrastructure, as well as between land price and population density, we do not include them in the same model.

To begin, we test the null hypothesis of no spatial correlation in the OLS residual by using Moran's I, the Lagrange multiplier, and Robust Lagrange multiplier tests. The results are presented in Table 1. The Moran's I tests are statistically significant at the 1% level in all models, indicating the existence of a spatial concentration in both years. The Lagrange multiplier tests are also statistically significant at the 1% level, which indicates the null hypothesis that no spatial correlation can be rejected at the 1% level for the spatial error and lag models. The Robust Lagrange multiplier test for the spatial error model is not statistically significant in 1992 and is statistically significant at the 10% level in 2012. In contrast, the Robust Lagrange multiplier test for the SLM is statistically significant at the 1% level in 1992 and 2012. This result suggests that we focus on the SLM in 1992 and 2012.

Based upon these results, we estimate the SAR tobit model to incorporate spatial dependence. The results are presented in Table 2 and show that the spatial lag parameter ρ is statistically significant in all models. These results indicate that private landfill sites for industrial waste have been consistently concentrated in some areas for more than 20 years. Thus, we found strong support for our first hypothesis, together with the result of Moran's I statistics. The fifth to eighth columns in Table 2 are robustness checks by estimations using the landfill site per land area (km^2) of municipality as a dependent variable. The result is similar to that of the model using the number of landfill sites per capita as a dependent variable.

Interestingly, the structure of the location of private landfill sites for industrial waste has been fairly stable for 20 years. In both 1992 and 2012, economic factors were decisive in determining the location of industrial-waste landfill sites. The amount of industrial waste and total revenue from manufacturing production are positive and statistically significant. These results show that the location of industrial-waste landfill sites is sensitive to the regional demand for a waste landfill. The total length of the highway infrastructure within a municipality is statistically significant and positive, suggesting that transportation infrastructure strongly affects landfill site locations. This result also implies that transportation costs constitute a significant part of landfill costs. Land price is statistically significant and negative in all models. This result is reasonable because a higher land price implies higher costs of locating sites. In addition, the estimated coefficient of land price in the 2012 model is two times higher than that of the 1992 model. The result suggests that the increasing cost as a result of stricter regulations might affect the distribution of sites to concentrate them in an area with lower construction and operating costs for waste disposal. Population density is also statistically significant and negative in all models. Although waste-management companies hope to find an optimal location for landfill operations, nearby residents often oppose site construction. The estimated coefficient of the population density in the 2012 model is larger than that of the 1992 model. These results suggest that the NIMBY issue is becoming more serious.

We found positive and statistically significant coefficients for the number of intermediate processing facilities for industrial waste per capita and the number of hazardous-waste landfill sites per capita in 1992 and 2012. Presumably, a larger number of waste-related facilities are associated with a larger number of industrial-waste landfill sites, which is in line with findings by Ishimura and Takeuchi (2017). In addition, the coefficient for population density is negative and statistically significant. These results suggest that industrial-waste landfill sites tend to be located in areas in which construction is easier, such as areas with an existing landfill site and lower transaction and opportunity costs. The publicly supported site variable is positive and statistically significant at the 10% level.

Regarding the environmental factor, the amount of groundwater usage is statistically significant with negative coefficients in all models. This result suggests that municipalities with more groundwater usage are less likely to locate landfill sites. Because a higher dependence on groundwater means a stronger possibility of pollution damage from the sites, the negative coefficient of the variable is in line with our expectation.

The unemployment variable is positive but not statistically significant in either year, which does not support the findings of Laurian and Funderburg (2014). The percentage of agricultural workers has a positive and statistically significant coefficient in 2012, whereas the percentage of manufacturing workers is negative and has a statistically significant coefficient in 1992 and 2012. These results indicate that waste-management companies tend to locate landfill sites in municipalities with larger populations of agricultural workers. The dummy variable for populations under 10,000 individuals is negatively correlated with the concentration of landfill sites, whereas the dummy variable for populations over 200,000 individuals is positively correlated. These results imply that landfill sites tend to be located in urban areas.

Policy variables, industrial-waste tax, and trade restrictions are not statistically significant in most models examined in this study. The industrial-waste taxation variable is positive and statistically significant in one model, but the statistical significance is weak, suggesting that these policy instruments have not affected the location of landfill sites very strongly, even though Sasao (2014) showed that waste-trade restrictions had some impact on the inflow of waste. Another complication regarding these variables is the endogeneity of polices. Prefectural governments likely introduce these policies when the number of sites in their administrative area is high. Thus, we examine the effect of policies by taking the incremental number of landfill sites as the dependent variable. Table 3 reports the estimation results of the effect of policy variables on the number of newly constructed sites. Note that because the number of newly constructed sites is only about 20 in Japan after 1997, we use prefectural-level panel data from 1992 to 2012. In addition, we attempt to capture the possible endogeneity of policy variables by using their lagged values in the estimation.[ix] All estimations are based on a panel tobit model[x] and 940 observations. We find that both dummy variables for industrial-waste tax and trade restrictions are negative and statistically significant. These results indicate that the implementation of an industrial-waste tax and trade restrictions on industrial-waste shipments decreases the number of private landfill sites constructed, which supports the findings by Mulatu and

Wossink (2014) and Stafford (2000). The coefficient for industrial-waste tax in the first column implies that prefectures with a waste-disposal tax have approximately 1.068 sites less than other prefectures. Similarly, waste-trade restrictions decrease the number of landfill sites in that prefecture by 1.415. Because the enforcement of local regulations affects disposal prices and, therefore, the demand for waste disposal, the new constructions are attracted to areas with lax regulations.

6. Conclusions

In this study, we have explored the mechanism behind the locational concentration of private landfill sites for industrial waste. The empirical results suggest that a spatial concentration of landfill sites existed over 20 years. Moreover, we found that the determinants of location have not changed for 20 years. Economic factors, such as input markets and transport infrastructure, play a significant role in determining the location of private landfill sites. Therefore, the differences in the geographical advantages and economic structures between regions would cause a spatial concentration of landfill sites. These findings suggest that even if the unwanted facility deals with “bads,” the locational concentration of these facilities adapt to the theory of spatial competition between companies dealing with “goods” (Hoteling 1929).

Our results provide several implications for addressing NIMBY issues. Although economic factors play a decisive role in locating landfill sites, this process might lead to the uneven distribution of unwanted facilities among local communities. In addition, our empirical results indicate that the implementation of local policies, such as an industrial-waste tax and trade restrictions, could have reduced the number of landfill sites in that prefecture. Although these policy instruments in a given area reduce the number of sites there, they might also shift the site locations to other areas, particularly to their neighborhood municipalities. In that sense, the concentration of landfill sites in some areas might be attributable to the lax regulations of local administrations. To mitigate NIMBY attitudes, developing policy coordination by multiple local governments in order to avoid a concentration of landfill sites is important.

The empirical results of this study also indicate that regions with lower land prices tend to attract landfill sites, and this tendency is stronger than it was 20 years ago. As many hedonic studies have suggested, a negative external economy of a waste-related facility causes land prices to decline around the site. This decline may cause a further concentration of unwanted facilities owing to their attraction to lower land prices. A possible extension of this study is to incorporate such spillover effects and the resulting agglomeration of facilities that further decrease land prices in their neighborhoods.

References

Anselin, L., 1988. Spatial econometrics: methods and models. Springer.

Anselin, L., 1995. Local indicators of spatial association—LISA. Geographical Analysis 27, 93–115.

Aldrich, D.P., 2008. Location, location, location: Selecting sites for controversial facilities. The Singapore Economic Review, 145–172.

The Economist, 2015. Waste Disposal: Keep the Fires Burning. The Economist. April 25th, 2015.

Feinerman, E., Finkelshtain, I., Kan, I., 2004. On a Political Solution to the NIMBY Conflict. The American Economic Review 94, 369–381.

Fortenbery, T.R., Deller, S.C., Amiel, L., 2013. The location decisions of biodiesel refineries. Land Economics 89, 118–136.

Frey, B.S., Oberholzer-Gee, F., 1996. Fair siting procedures: an empirical analysis of their importance and characteristics. Journal of Policy Analysis and Management 15, 353–376.

Galka, M., 2016. What does New York do with all its trash? One city's waste–in numbers. The Gurardian, Thursday 27, October 2016. https://www.theguardian.com/cities/2016/oct/27/new-york-rubbish-all-that-trash-city-waste-in-numbers (accessed April 27, 2018)

Geospatial Information Authority of Japan, 2015. Kokudosuchijouhou haikibutsushorishisetsu data [Data on land price from the Geographic Information Systems (GIS) database], in Japanese. http://nlftp.mlit.go.jp (accessed April 27, 2018)

Getis, A., Ord, J.K., 1992. The analysis of spatial association by distance statistics. Geographical Analysis 24, 189–206.

Hiroshima Prefecture, 2011. Sangyohaikibutsu zeiseido wo donyushiteiru zititai no zyokyo [The 2011 survey report on the condition of local government implementing industrial waste tax] https://www.pref.hiroshima.lg.jp/uploaded/attachment/41035.pdf (accessed on January 29, 2018) Hiroshima, Japan, in Japanese.

Hokkaido Prefecture, 2012. Hokkaido sangyohaikibutsu syori joukyo chousa kekka gaiyou [The summary of industrial waste management in Hokkaido Prefecture] http://www.pref.hokkaido.lg.jp/ks/jss/zittaityousa/H24tyousakettuka.pdf (accessed on October 12, 2015)

Hoteling, H., 1929. Stability in Competition. Economic Journal 39, 41–57.

Ishimura, Y., Takeuchi, K., 2017. Does Conflict Matter? Spatial Distribution of Disposal Sites in Japan. Environmental Economics and Policy Studies 19, 99–120.

Japan Leasing Association, 2015. Sangyohaikibutsusyori gyosei ni kansuru tyosakekka [Survey report on administration of industrial waste] Tokyo, Japan, in Japanese.

Japanese Ministry of Internal Affairs and Communications, 1990, 2000, and 2010. Kokusei chousa 2010 [2010 national census], Tokyo, Japan, in Japanese.

Japanese Ministry of Internal Affairs and Communications, 1992, 2002, and 2012. Heisei 4 nendo, 14 nendo, and 24 nendo chihoukoukyoudantai no shuyo zaisei sihyou ichiran [the financial indicators of local governments 2012], Tokyo, Japan, in Japanese.

Japanese Ministry of the Environment, 1993, 2003, and 2013. Heisei 4 nendo, 14 nendo, and 24 nendojigyou sangyouhaikibutsu gyouseisoshikitou houkokusho [Survey report on administrative organizations for industrial waste 1992, 2002 and 2012], Tokyo, Japan, in Japanese.

Japanese Ministry of Agriculture, and Fisheries, 1991, 2003 and 2011. Nougyouyouchikasui no riyoujittai: dai 5 kai nougyouyouchikacui no riyoujittaichousa no gaiyou [The usage of groundwater for agriculture: a summary of the third, forth, and fifth survey on the usage of groundwater for agriculture], Rural Environment Division, Rural Development Bureau, Tokyo, Japan, in Japanese. http://www.maff.go.jp/j/nousin/sigen/pdf/chikasui.pdf (accessed April 27, 2018)

Japanese Ministry of the Environment, 1992, 2002, and 2012. Sangyohaikibutsu haishutsushori joukyouchousa houkokusho 1992, 2002, and 2012 [Survey report on industrial waste emissions and disposal1992, 2002, and 2012], Tokyo, Japan, in Japanese.

Japanese Ministry of the Environment, 2014. History and Current State of Waste Management in Japan, Tokyo, Japan, in Japanese.

Japanese Ministry of Economy, Trade and Industry, 1992, 2002, and 2012. Heisei 4 nendo, 14 nendo, and 24 nen kougyou toukei chousa [The 1992, 2002, and 2012 census of manufacturers], Tokyo, Japan, in Japanese.

Japanese Ministry of Land, Infrastructure, Transport and Tourism, 1992, 2002, and 2012. Douro tokei nenpou 1992, 2002, and 2012 [Annual report of road statistics 1992, 2002, and 2012], Tokyo, Japan, in Japanese.

Kunreuther, H., Kleindorfer, P.R., 1986. A sealed-bid auction mechanism for siting noxious facilities. American Economic Review 76, 295–299.

Laurian, L., Funderburg, R., 2014. Environmental justice in France? A spatio-temporal analysis of incinerator location. Journal of Environmental Planning and Management 57, 424–446.

LeSage, J.P., 1999. Applied econometrics using Matlab. Department of Economics, University of Toledo.

LeSage, J.P., 2000. Bayesian estimation of limited dependent variable spatial autoregressive models. Geographical Analysis 32, 19-35.

LeSage, J.P., Pace, R.K., 2009. Introduction to spatial econometrics. Taylor & Francis Group.

Minehart, D., Neeman, Z., 2002. Effective siting of waste treatment facilities. Journal of Environmental Economics and Management 43, 303–324.

Mulatu, A., Wossink, A., 2014. Environmental regulation and location of industrialized agricultural production in Europe. Land Economics 90, 509–537.

Ord, J.K., Getis, A., 1995. Local spatial autocorrelation statistics: distributional issues and an application. Geographical Analysis 27, 286–306.

Sakai, T., 2012. Fair waste pricing: an axiomatic analysis to the NIMBY problem, Economic Theory 50, 499–521.

Sasao, T., 2004. Analysis of the socioeconomic impact of landfill siting considering regional factors. Environmental Economics and Policy Studies 6, 147–175.

Sasao, T., 2014a. Does Industrial Waste Taxation Contribute to Reduction of Landfilled Waste? Dynamic Panel Analysis Considering Industrial Waste Category in Japan, Waste Management 34, 2239–2250.

Sasao, T., 2014b. Industrial Waste Shipments and Trade Restrictions, In: T. Kinnaman and K. Takeuchi (eds.) "Handbook on Waste Management," Edward Elgar Publishing, Ch.7, 186–215.

Stafford, S.L., 2000. The impact of environmental regulations on the location of firms in the hazardous waste management industry. Land Economics 76, 569–589.

Swallow, S.K., Opaluch, J.J., Weaver, T.F., 1992. Siting noxious facilities: an approach that integrates technical, economic, and political considerations. Land Economics 68, 283–301.

Tables

Table 1: Estimation results: Ordinary least squares

	Number of landfill sites for industrial waste per residents							
	1992				2012			
	Coef.		Coef.		Coef.		Coef.	
Landfill site for hazardous waste	0.260	***	0.256	***	0.272	***	0.269	***
	(0.083)		(0.082)		(0.036)		(0.036)	
Intermediate site for industrial waste	0.047	*	0.012		0.054	**	0.008	
	(0.028)		(0.027)		(0.023)		(0.022)	
Publicly supported landfill site	0.026		0.021		0.075		0.064	
	(0.064)		(0.064)		(0.064)		(0.064)	
Population density	−0.002	***			−0.001	**		
	(0.001)				(0.001)			
Land price			0.000				0.000	
			(0.000)				(0.001)	
Unemployment	−0.008		−0.004		−0.003		0.000	
	(0.011)		(0.011)		(0.007)		(0.007)	
Agricultural workers	0.009	***	0.008	***	0.015	***	0.015	***
	(0.003)		(0.003)		(0.004)		(0.004)	
Manufacturing workers	−0.003		−0.004		−0.004		−0.012	***
	(0.003)		(0.003)		(0.004)		(0.004)	
Municipal financial stability index	−0.039		0.035		−0.039		0.001	
	(0.055)		(0.053)		(0.066)		(0.066)	
Population under 10,000	−0.027		−0.041		−0.042		−0.065	*
	(0.034)		(0.034)		(0.037)		(0.037)	
Population over 200,000	0.008		−0.045		−0.020		−0.059	
	(0.063)		(0.059)		(0.063)		(0.059)	
Nature reserve	−0.020		−0.013		−0.048		−0.048	
	(0.032)		(0.032)		(0.033)		(0.033)	
Amount of groundwater	0.000	*	0.000		0.000		0.000	
	(0.000)		(0.000)		(0.000)		(0.000)	
Total manufacturing revenue	0.000		0.000		0.000		0.000	
	(0.000)		(0.000)		(0.000)		(0.000)	
Amount of industrial waste	0.103	***			0.154	***		
	(0.015)				(0.014)			
Length of highway infrastructure			0.090	***			0.089	***
			(0.010)				(0.008)	
Industrial-waste tax					0.024		0.017	
					(0.031)		(0.031)	
Waste-trade restriction	0.027		0.008		−0.010		−0.012	
	(0.035)		(0.034)		(0.038)		(0.037)	
Intercept	0.016		−0.026		−0.101		−0.008	
	(0.089)		(0.088)		(0.101)		(0.096)	
Moran's I	0.090	***	0.078	***	0.063	***	0.062	***
LM err	31.606	***	23.888	***	15.346	***	14.783	***
LM lag	35.134	***	25.572	***	18.985	***	18.554	***
RLM err	2.027		1.075		2.988	*	3.565	*
RLM lag	5.556	**	2.759	*	6.628	**	7.336	***
Obs.	1,692		1,692		1,692		1,692	

Note: Standard errors are given in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2: Estimation results: Spatial tobit model (MCMC)

	Number of landfill sites for industrial waste per residents				*Number of landfill sites for industrial waste per area*			
	1992		2012		1922		2012	
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
Landfill site for hazardous waste	0.836***	0.720***	0.543***	0.540***	1.658***	1.455**	0.522***	0.546***
	(0.267)	(0.251)	(0.116)	(0.117)	(0.621)	(0.586)	(0.168)	(0.173)
Intermediate site for industrial waste	0.296***	0.188**	0.221**	0.244***	0.638***	0.413*	0.279**	0.358***
	(0.097)	(0.095)	(0.087)	(0.083)	(0.219)	(0.219)	(0.121)	(0.122)
Publicly supported landfill site	0.350*	0.276	0.364*	0.488**	0.872*	0.715*	0.334	0.517
	(0.201)	(0.181)	(0.216)	(0.217)	(0.465)	(0.428)	(0.293)	(0.321)
Population density	−0.016***		−0.049***		−0.034***		−0.063***	
	(0.003)		(0.010)		(0.007)		(0.011)	
Land price		−0.022***		−0.048***		−0.053***		−0.083***
		(0.005)		(0.013)		(0.008)		(0.028)
Unemployment	−0.042	−0.033	−0.017	−0.023	0.021	0.018	0.017	0.009
	(0.043)	(0.042)	(0.030)	(0.029)	(0.096)	(0.100)	(0.042)	(0.043)
Agricultural workers	0.013	0.009	0.034**	0.034**	−0.002	−0.013	0.022	0.025
	(0.011)	(0.010)	(0.014)	(0.014)	(0.025)	(0.026)	(0.020)	(0.022)
Manufacturing workers	−0.020*	−0.025**	−0.026	−0.041***	−0.020	−0.033	−0.033	−0.043*
	(0.011)	(0.011)	(0.017)	(0.015)	(0.025)	(0.024)	(0.024)	(0.023)
Municipal financial stability index	−0.064	0.348*	0.552*	0.315	0.622	1.465***	1.630***	1.333***
	(0.208)	(0.202)	(0.291)	(0.287)	(0.452)	(0.462)	(0.369)	(0.407)
Population under 10,000	−0.828***	−0.827***	−1.074***	−1.153***	−2.069***	−2.101***	−1.895***	−2.087***
	(0.159)	(0.145)	(0.166)	(0.177)	(0.343)	(0.351)	(0.262)	(0.304)
Population over 200,000	0.613***	0.403**	0.855***	0.540**	1.170**	0.916**	1.229***	0.928***
	(0.217)	(0.205)	(0.257)	(0.239)	(0.466)	(0.460)	(0.351)	(0.346)
Nature reserve	0.044	0.034	−0.132	−0.038	0.205	0.172	−0.196	−0.045
	(0.115)	(0.111)	(0.133)	(0.134)	(0.272)	(0.254)	(0.195)	(0.191)
Amount of groundwater	−0.001**	−0.001**	−0.001**	−0.001*	−0.002***	−0.002***	−0.002***	−0.002**
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Total manufacturing revenue	0.002**	0.003***	0.002	0.002**	0.005**	0.007***	0.003*	0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Amount of industrial waste	0.201***		0.322***		0.272**		0.286***	
	(0.052)		(0.054)		(0.116)		(0.073)	
Length of highway infrastructure		0.227***		0.174***		0.355***		0.166***
		(0.035)		(0.031)		(0.084)		(0.045)

Industrial-waste tax			0.205*	0.138			0.380**	0.342*
			(0.119)	(0.121)			(0.165)	(0.178)
Waste-trade restriction	0.183	0.181	0.047	0.118	0.412	0.419	0.136	0.255
	(0.121)	(0.113)	(0.147)	(0.148)	(0.264)	(0.257)	(0.206)	(0.216)
ρ	0.305***	0.240***	0.211***	0.238***	0.288***	0.255***	0.246***	0.274***
	(0.051)	(0.049)	(0.054)	(0.054)	(0.048)	(0.051)	(0.051)	(0.057)
Intercept	−0.865***	−1.036***	−1.703***	−1.622***	−2.375***	−2.560***	−2.650***	−2.805***
	(0.332)	(0.322)	(0.417)	(0.413)	(0.773)	(0.794)	(0.595)	(0.631)
Obs.	1,692	1,692	1,692	1,692	1,692	1,692	1,692	1,692

Note: Standard errors are given in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 3: Estimation results: Panel tobit model

	Number of new disposal sites for industrial waste					
	sites		*per residents*		*per area*	
	Coef.		Coef.		Coef.	
Industrial-waste tax	−1.068	**	−0.058	***	−2.307	***
	(0.482)		(0.020)		(0.713)	
Waste-trade restriction	−1.415	***	−0.059	***	−1.607	**
	(0.510)		(0.020)		(0.702)	
Population density	−0.322	***	−0.010	***	−0.250	***
	(0.072)		(0.002)		(0.070)	
Land price	−1.656	***	−0.075	***	−2.696	***
	(0.517)		(0.021)		(0.732)	
Nature reserve	−2.646	*	−0.087	*	−2.835	**
	(1.555)		(0.049)		(1.296)	
Amount of groundwater	0.409		0.018	**	0.574	**
	(0.264)		(0.009)		(0.292)	
Total manufacturing revenue	2.671	***	0.060	*	3.357	***
	(0.998)		(0.033)		(0.989)	
Amount of industrial waste	0.241	***	0.007	**	0.097	
	(0.092)		(0.003)		(0.092)	
Length of highway infrastructure	−0.031	***	−0.001	***	−0.015	***
	(0.005)		(0.000)		(0.006)	
Intercept	5.426	***	0.196	***	5.248	***
	(1.503)		(0.053)		(1.734)	
Log likelihood	−1,117.421		−138.531		−1,276.756	
Wald-χ2	136.6		96.47		78.3	
Obs.	940		940		940	

Note: Standard errors are given in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Figure titles

Figure 1: Spatial clustering of landfill sites via Getis–Ord Gi* of 1992

Figure 2: Spatial clustering of landfill sites via Getis–Ord Gi* of 2012

Figure 3: Locations of industrial-waste landfill sites operating in 1992

Figure 4: Locations of industrial-waste landfill sites operating in 2012

Figure 1: Spatial clustering of landfill sites via Getis–Ord Gi* of 1992

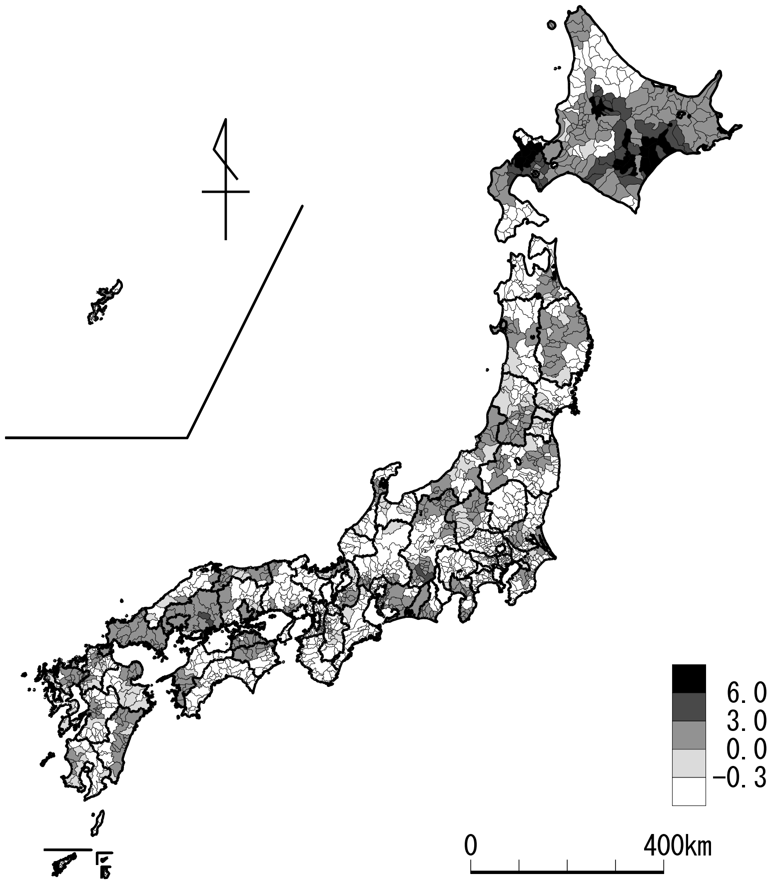


Figure 2: Spatial clustering of landfill sites via Getis–Ord Gi* of 2012

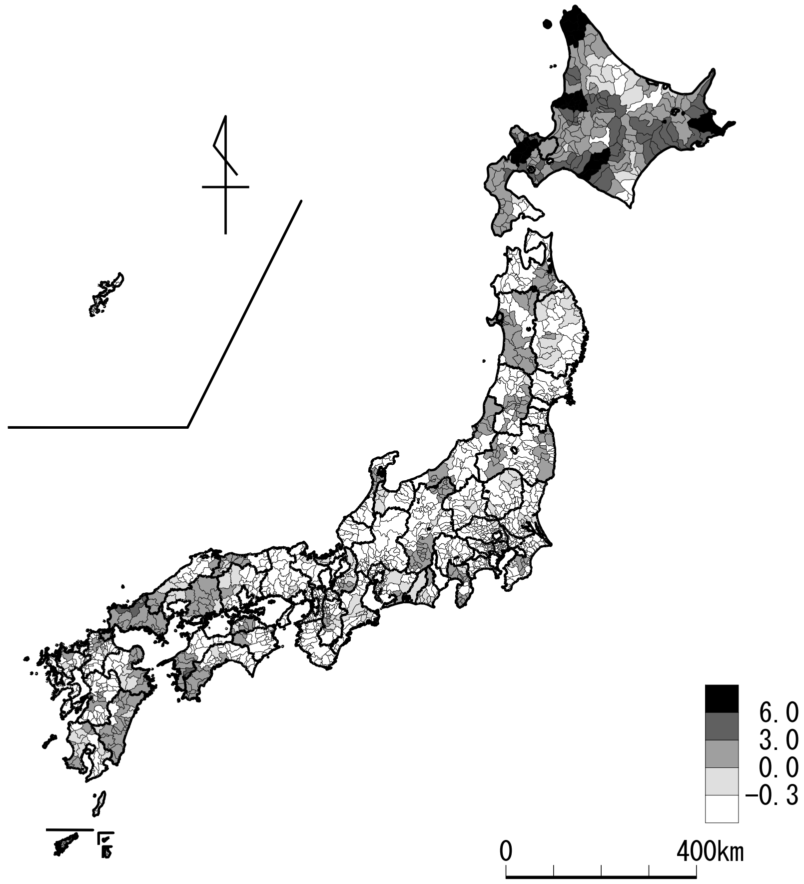


Figure 3: Locations of industrial-waste landfill sites operating in 1992

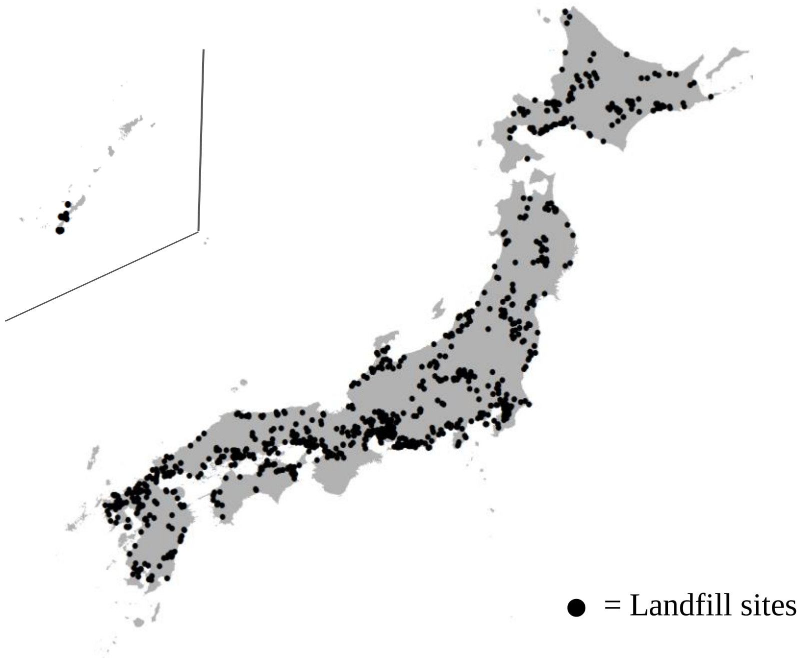
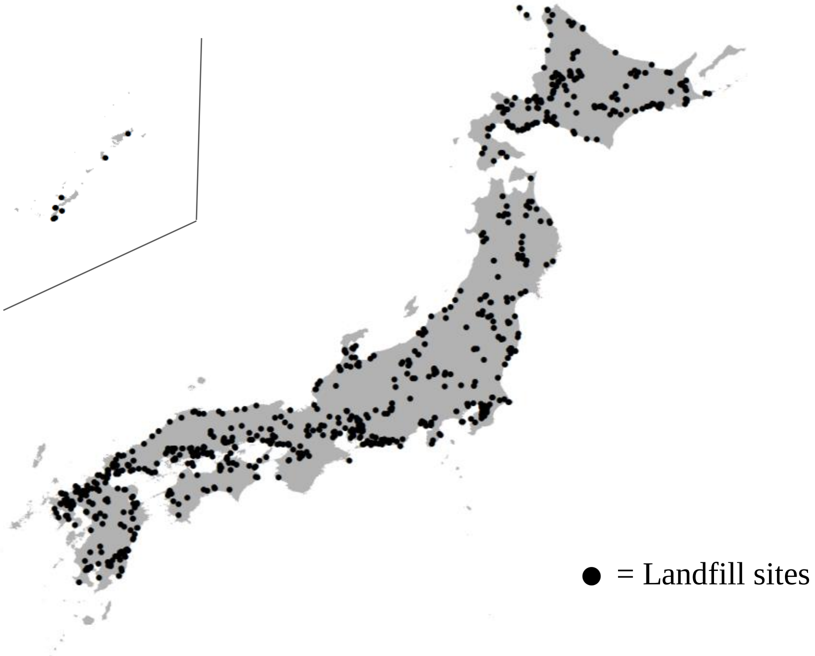


Figure 4: Locations of industrial-waste landfill sites operating in 2012



Footnotes

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[i] Previous studies on the location of waste treatment facilities mainly focused on normative issues. Kunreuther and Kleindorfer (1986) proposed a sealed-bid mechanism to elicit citizens' willingness to accept facilities. Minehart and Neeman (2002) presented a modified second-price auction procedure for choosing a site location. Swallow et al. (1992) proposed a three-phased approach that integrates the technical, economic, and political dimensions related to the landfill-siting process.

[ii] Ishimura and Takeuchi (2017) examined the spatial concentration of landfill sites for industrial waste by using cross-sectional data in 2012.

[iii] Local Japanese governments are divided into two tiers: prefectural governments and municipalities (cities, towns, and villages). The nation has 47 prefectures. The number of municipalities was 1,724 as of April 2018.

[iv] Data on landfill site shipments before 2000 are not available.

[v] Data on the amount of industrial waste generated and highway length at the municipality level are unavailable.

[vi] http://www.env.go.jp/park/doc/data.html (accessed April 27, 2018).

[vii] In Japan, a local municipality with more than 200,000 inhabitants is defined as a large city.

[viii] Because all prefectures apply same tax rate, it is not possible to use the level of tax rate for the industrial-waste tax variable.

[ix] Considering the endogeneity of policy variables, we remove the variables for intermediate processing facilities, hazardous-waste landfill sites, and public landfill sites from the explanatory variables in the estimation.

[x] Because prefectural-level data are too crude, we do not use the spatial tobit model; instead, use an ordinary tobit model as the regression model. In addition, for a similar cause, we do not use the explanatory variables related to municipal-level data.