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The Spatial Concentration of Waste Landfill Sites in Japan

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The Spatial Concentration of Waste Landfill Sites in Japan

Abstract

This study investigates the spatial concentration of waste landfill sites in Japan over two decades. Using a unique dataset of 2,164 industrial-waste landfill sites from 1992 to 2012, we find robust evidence of a persistent spatial concentration of sites managed by private companies. The empirical results show that economic factors and the existence of other waste-related facilities have a positive effect on the private landfill site location. Interestingly, this relationship has been fairly stable for twenty years despite a significant decline in the number of sites in operation. In addition, we find that prefectural-level policies tend to decrease the opening of new landfill sites in the area. These results highlight the role of public intervention in mitigating a concentration of facilities that might be undesirable to neighbors.

1. Introduction

The location of waste-related facilities is often the cause of contentious disputes. A typical example is a solid waste landfill site: local residents are reluctant to live near landfill sites, even though most people understand the importance to society of such facilities. In large cities, finding an appropriate location for a waste landfill may be challenging; for example, New York City, where land available for waste disposal is in short supply, transports much of its municipal solid waste by truck, train, and barge to landfill sites 600 miles away from the city (Galka, 2016). The situation is also critical in rapidly growing economies that produce large amounts of waste. Cities in China are running out of suitable sites for landfills and are turning to incinerators, although their construction also faces opposition by and protests from residents (The Economist, 2015).

Japan's population is extremely dense and its land resources are scarce; thus, it provides an excellent setting for studying the location of waste-related facilities. According to our survey, described in Section 4.2, a total of 893 industrial-waste landfill sites were operating in 2012, concentrated in only 25% of Japanese municipalities. Is there any geographical advantage, such as abundance of waste inputs and available land for disposal, regarding the location of an undesirable facility dealing with "bads?" What are the determinants of the spatial concentration of landfill sites? Since they have decreased in number in Japan over time due to a steady increase in recycling, has their spatial distribution changed accordingly? This study explores landfill site locations in detail over two decades in an attempt to answer these questions.

We investigate the spatial distribution of industrial-waste landfill sites using a unique dataset of 2,164 landfill sites in Japan from 1992 to 2012, and analyze changes in the spatial concentration of landfill sites and factors that may affect their location. The first contribution of this study is exploration of the spatial distribution of landfill sites over time. Because long-term data are rarely available, to the best of our knowledge, only a few studies have empirically examined the determinants of waste landfill site locations.[1] In this study, we addressed this issue by requesting data disclosure from all Japanese local governments that are in charge of site location licensing. As a result, we collected comprehensive location data on 2,164 private and public industrial-waste landfill sites that operated from 1992 to 2012. We aggregated the data at the municipality level and combined them with information on 1,692 local

[1] Previous studies on the location of waste treatment facilities have 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.

municipalities to analyze the determinants of the spatial concentration of landfill sites. The municipality-level data provide detailed information on the characteristics of local communities that are likely to host private landfill sites.

The second contribution of this study is an investigation of how market forces affect the location of facilities that might generate negative reactions from residents. Landfill site location as the result of a market equilibrium differs from the outcome of a political equilibrium. Private firms pursue profit maximization (or cost minimization) when locating their plants and facilities, while governments focus on social welfare or political support from the industrial sector and local community. Therefore, differences are likely to exist between private and public 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., Baden and Coursey, 2002; Feinerman et al., 2004; Aldrich, 2008; Laurian and Funderburg, 2014; Cohen et al., 2016). However, the extent to which political factors erode the economic decision-making of private firms has not been adequately investigated in the case of locating unwanted facilities.

Our empirical results show that a spatial concentration of landfill sites persisted in Japan from 1992 to 2012. Economic factors, such as land price, industrial-waste volume, and the industrial structure, play a significant role in the location patterns of landfill sites managed by private companies. Interestingly, this relationship has been fairly stable for twenty years despite a significant decline in the number of operating landfill sites. These results suggest that market forces strongly affect the concentration of landfill sites. In addition, we find that prefectural regulations reduced the number of new landfill site openings in that area. These results suggest the critical role of public intervention in addressing the concentration of unwanted facilities.

This study relates to the pollution haven hypothesis literature, which examines the impact of environmental regulation on the location of a polluting industry.[2] For instance, Stafford (2000) examined the impact of environmental regulations on the location decisions of hazardous-waste management firms. The results indicate that state enforcement of environmental regulations affects the cost of providing waste management and, therefore, serves as an essential driver for the location decisions of waste management firms. Mulatu and Wossink (2014) addressed European Union (EU) pig industry locations and found that highly polluting industrial sectors are attracted to jurisdictions with lax environmental regulations. Building upon these studies, this research investigates the impact of local regulation on the

[2] Exploring the international trade of waste, Kellenberg (2012) shows that the differences in environmental regulations across countries play a significant role in determining trade flow. Baggs (2009) finds that countries that import less hazardous waste tend to have higher per capita income.

spatial concentration of economic activities that potentially result in negative externalities for communities.

The remainder of this article is organized as follows. Section 2 describes the background of industrial-waste management in Japan. Section 3 explains the method used to estimate spatial dependence. Section 4 describes the study's empirical strategy, model specification, and data, while Section 5 provides the results of the analysis of the spatial concentration of landfill sites. Section 6 concludes and discusses policy implications.

2. Background

2.1 Industrial waste management in Japan

In Japan, waste is classified as industrial or municipal solid waste, and separate regulations are applied under the Waste Management and Public Cleansing Act (hereafter, the Waste Management Act) of 1970. Industrial waste is produced by business activities such as manufacturing, construction, agriculture, and the fishing industry. Approximately 13 million tons of industrial waste were disposed of in landfill sites in 2012, three times more than the amount of municipal solid waste (Japanese Ministry of the Environment, 2012). Business operators resort to waste-management companies to dispose of their waste and pay disposal costs. After separation for recycling or incineration, industrial waste is disposed of in landfill sites managed by private companies, while municipal solid waste is disposed of in sites managed by local municipalities.[3] Thus, the management of industrial waste is based on market mechanisms. In Japan, 953 establishments have permission for industrial-waste disposal, and 20 establishments newly entered this market in 2012. The number of private landfill sites in operation is 893, and the total residual capacity of these sites is about 117 million m^3.

Under competitive market conditions, waste-management companies choose their site locations based on profit maximization without considering the impacts of geographical site concentration. Therefore, industrial-waste landfill site location might generate uneven distribution of unwanted facilities in the long run. Using cross-sectional data for Japanese municipalities in 2012, Ishimura and Takeuchi (2017) found that a spatial concentration of industrial-waste landfill sites exists in areas where other waste-related facilities already existed. Spatial concentration might lead to environmental degradation, as suggested by Ichinose and

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

Yamamoto (2011), and a greater number of landfill sites might relate to the higher incidence of illegal dumping. Moreover, the concentration of landfill sites might make construction of new facilities more difficult. For example, Sasao (2004) indicated that the sense of unfairness related to treating waste generated by other communities is a major reason for residents' opposition to waste treatment facilities.

2.2 Industrial-waste landfill sites in Japan

The Japanese Ministry of the Environment (MOE) has taken measures to mitigate strong opposition from residents regarding the construction of landfill sites and assure sufficient capacity for waste landfill (Japanese Ministry of the Environment, 2014). Based on the 1991 amendment to the Waste Management Act, the MOE requires companies managing landfill sites to obtain permission from the prefectural government before commencing construction and closing sites.[4] Companies must follow environmental assessment procedures and construct sites following the technical standards for treatment facilities and site structures. As long as a company's application satisfies the law, prefectural governments must approve the construction.

[4] See, Article 15, Clause 1 of the Waste Management Act.

Although prefectural governments are responsible for issuing the permits, they 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 the amendment to the Waste Management Act. This revision included establishing a maintenance reserve fund, restricting permissions to construct and close landfill sites, and developing standards for facility structures and operations (Murata, 1998). In addition, since 1998, the Waste Management Act has required landfill site constructors to investigate the effect on neighborhoods of noise, stench, water, and soil pollution. Furthermore, since 1999, when applying for prefectural permission to construct a landfill site, the Environmental Impact Assessment Act has required waste-management companies to submit environmental assessment reports, which include public opinion on the matter (Ueta and Kitagawa, 2001).

Stricter regulation of landfill sites has made the market for waste landfills more competitive, and tightening of environmental regulations has increased the cost of operating and managing landfill sites. Due to the promotion of recycling used materials, the amount of industrial waste disposed of in landfill sites has been decreasing. As a result, according to our survey results, the number of landfill sites in operation has decreased by 34% from 1999 to 2012. These factors together have likely affected the distribution of sites and caused a higher concentration in areas with lower operating costs and a higher-than-ever demand for waste landfills.

2.3 Local regulations on industrial-waste disposal

In addition to federal regulations, local governments can also affect waste facility location decisions. The local government's enforcement of environmental regulations affects the cost of providing waste management and, therefore, significantly affects the location decisions of waste management firms (Stafford, 2000). In this subsection, we describe two policy instruments utilized by Japanese prefectures: the industrial-waste tax and waste-trade restrictions. In Japan, more than half of prefectures enforce these instruments to regulate industrial waste disposal.

Industrial-waste tax

The industrial-waste tax is a local tax; the amount assessed is based on the volume of industrial waste. The first industrial-waste tax was introduced in 2002 by Mie Prefecture, and since then 28 prefectures have enforced similar taxes. These prefectures have all applied a tax of 1,000 yen (about nine dollars) per ton of waste disposal. The taxes are collected from waste generators or landfill sites, depending on the prefecture. In the latter case, it is passed on to waste generators on top of the landfill price. Sasao (2014a) found that industrial-waste taxes in Japan have minimal effects on the amount of landfill. Although the primary aim of industrial-waste taxes is to raise local tax revenue and reduce the amount of landfill, they might also provide an incentive for waste-management companies to choose their site locations in prefectures that do not collect such taxes and, therefore indirectly affect the concentration of landfill sites in the long-run.

Waste-trade restrictions

Trade restrictions on industrial waste are intended to limit the import of industrial waste from other prefectures. Inter-prefectural shipment of industrial waste is restricted in various forms in 33 prefectures. In the strictest case, some prefectures prohibit importing waste from other prefectures. Waste cannot be exported to landfill sites within prefectures that implement such restrictions. In other cases, prefectural governments require prior notification, consultation, or approval of inter-prefectural shipment. Waste generators and waste disposal contractors in the origin prefecture must declare to, consult with, or obtain permission from the prefectural government in the destination area before transporting waste. Sasao (2014b) showed that waste-trade restrictions decrease the inflow of waste to landfill sites.

These policies affect the profit of waste-management companies through higher landfill prices and lower demand for waste disposal. Thus, introduction of an industrial-waste tax and waste-trade restrictions indirectly affect the concentration of landfill sites by shifting site locations to prefectures that do not impose such policies. On the other hand, the implementation of these policy instruments is potentially affected by the demand for industrial waste disposal; hence, the direction of causality needs to be established. In our empirical analysis, we use data on newly opened landfill sites to deal with the potential endogeneity of waste disposal policies.

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:

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

where x_i is the number of industrial-waste landfill sites per resident in municipality i, $(x_i - \bar{x})$ is the deviation from the average 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 of industrial-waste landfill sites are described in Section 4. 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:

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

where c_{ij} takes the value of 1 when municipality i and j are contiguous, and 0 otherwise. The spatial weight matrix w is based on the actual neighboring relationships between municipalities using queen-type contiguity (Appendix A).

Table 1 reports the results of the Global Moran's I statistics from 1992 to 2012 and their *p*-values. The results suggest that spatial dependency exists within site locations at the 1%

significance level for each year. These results indicate that an agglomeration of waste landfill sites existed in some areas during the sample period.

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

$$G^* = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{i,j} x_i x_j}{\sum_{i=1}^{N}\sum_{j=1}^{N} x_i x_j}. \tag{3}$$

The G* statistic calculated for each municipality is a Z score. A positive and large Z score value indicates intense clustering of high values, while a negative and small Z score value indicates intense clustering of low values. The clustering of landfill sites for 1992 and 2012 is presented in Figure 1. The G* statistics tend to be high for municipalities in Hokkaido prefecture, which is the northernmost of the four main islands of Japan. This result is reasonable, because Hokkaido has the largest livestock production in Japan, with many livestock farmers, particularly in the Southeastern area. According to Hokkaido prefecture (2012), half the total industrial waste in the prefecture is composed of animal manure. Thus, the livestock sector supplies a large amount of waste that leads to a higher demand for landfills. In addition, Hokkaido is the largest prefecture in terms of land area and is sparsely populated; therefore, more land is available for waste landfills than in other prefectures. Figure 1 suggests that, during the study period, the landfill site cluster has moved toward the northwest from the southeast in Hokkaido prefecture.

<Table 1>

<Figure 1>

4. Econometric Methodology

4.1 Model specifications

We conduct a cross-sectional regression analysis for nonnegative count data. Data on the number of landfill sites in each municipality are strongly skewed to the right with an accumulation of observations at zero. Therefore, count data models such as Poisson and negative binomial models are appropriate. As our data show significant over-dispersion with the variance being greater than the mean, we employ the negative binomial estimator. The estimation formula is as follows:

$$\mathrm{E}(Y_i) = \exp(\mathbf{x}_i\beta + \varepsilon_i), \tag{4}$$

where Y_i is the number of private landfill sites per 10,000 residents in municipality i; $\mathbf{x}_i$ is the vector of independent variables; ε_i is an unobserved heterogeneity term assumed to follow a gamma (θ,θ) distribution with $\mathrm{E}(\varepsilon_i) = 1$ and $\mathrm{Var}(\varepsilon_i) = 1/\theta$:

$$\mathrm{g}(\varepsilon_i) = \frac{\theta^\theta}{\Gamma(\theta)}\varepsilon_i^{\theta-1}\exp\{-\theta\varepsilon_i\}, \tag{5}$$

where $\mathrm{g}(\varepsilon_i)$ is the probability density function of ε_i. Then, the density of Y_i given $\mathbf{x}_i$ is derived as

$$f(y_i|\mathbf{x}_i) = \frac{\Gamma(y_i+\theta)}{y_i!\Gamma(\theta)}\left(\frac{\theta}{\theta+\mu_i}\right)^\theta\left(\frac{\mu_i}{\theta+\mu_i}\right)^{y_i}. \tag{6}$$

Substituting $\alpha = 1/\theta$ ($\alpha>0$), the negative binomial distribution can then be rewritten as

$$f(y_i|\mathbf{x}_i) = \frac{\Gamma(y_i+\alpha^{-1})}{y_i!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_i}\right)^{\alpha^{-1}}\left(\frac{\mu_i}{\alpha^{-1}+\mu_i}\right)^{y_i}, \tag{7}$$

where $\mu_i = \exp(\mathbf{x}_i\beta)$. In this study, we employ the negative binomial model with variance function $\mathrm{Var}[y_i|\mathbf{x}_i,\alpha] = \mu_i + \alpha\mu_i^2$, which is referred to as the NB2 model. In addition, when α = 0, the variance equals the mean, which indicates the absence of over-dispersion and a Poisson distribution can be used. Thus, in Section 5.1, we test the hypothesis that α = 0 using the likelihood-ratio test.

4.2 Data and explanatory variables

The locations of industrial-waste landfill sites in Japan have not been made publicly available; prefectural governments obtain this information through the construction permission process. Hence, we sent requests to all prefectural governments in Japan for information disclosure on landfill sites after 1992, the year when the licensing system for landfill sites was initiated. As a result, we obtained information on the location, operating period, 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 was 1,071 in 1992 and 823 in 2012.

Figure 2 illustrates the number of industrial-waste landfill sites operating each year. The number of landfill sites increased until 1998 and then decreased by 34% from 1999 to 2012.

We find that 72% of Japanese municipalities in 1992 (75% in 2012) had no industrial landfill sites.

<Figure 2>

The location data cover 1,692 municipalities in Japan that share a border with at least one other municipality and are aggregated at the municipality level. Municipality-level data provide detailed information for investigating the locations of private landfill sites by considering the characteristics of local communities that host landfill sites. To adequately analyze the concentration of landfill sites, prefectural-level data are insufficient, as they do not precisely reflect the geographical distribution of sites. For instance, if the total number of landfill sites in two prefectures are the same, prefectural-level data cannot distinguish between the case where all landfill sites are concentrated in a few municipalities within the prefecture and that where the sites are evenly distributed across all municipalities. Moreover, long-term data enable us to investigate changes in the spatial distribution of waste landfill sites. Since industrial-waste landfill sites operate for an average of 11 years, their locations could have changed considerably during the sample period (that is, 20 years). Out of 893 private landfill sites operating in 2012, less than half (398 sites) had been operating since 1992.

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

Economic factors

Economic factors such as private costs and benefits for waste-management companies may affect the location of landfill sites in some municipalities. This study uses three variables relating to economic factors: (1) the amount of industrial waste generated at the prefectural level, (2) the revenue from the local manufacturing sector's production at the municipal level, and (3) land price measured at the municipal level. The amount of industrial waste captures the supply of waste for landfills within the prefecture.[5] Fortenbery et al. (2013) suggest that input markets have a significant effect on the location of biodiesel refineries; a similar effect might significantly impact the location of waste landfill sites. The input for industrial waste landfill sites is the waste generated by industrial activities. The total production revenue of the local manufacturing sector captures the demand for waste landfill in the municipality and the local

[5] Data on the amount of industrial waste generated at the municipality level are unavailable.

economic performance of each municipality. Land price is a significant component of the fixed cost faced by companies that construct landfill sites. Although possible endogeneity of the land price may be a concern, we consider this does not apply to our case. Because we use the *average* land price in each municipality, with an average area of 213 km^2, it is unlikely that the price level is strongly affected by the existence of landfill sites. Hedonic property studies found the effect of contaminated sites on land prices is highly localized, typically within one or two km of distance (Currie et al., 2013; Taylor et al., 2016; and Walsh and Mui, 2017). In the estimation model for new landfill site openings, we use the lagged values of average land prices to mitigate endogeneity concerns.

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). The average land price in each municipality is obtained from land-price investigations by prefectural governments. Land-price data for each year are derived from the Geographic Information Systems (GIS) database of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (2015, 2019).

Existence of other waste-related facilities

The existence of other waste-related facilities can affect the location of industrial-waste landfill sites. Three variables are used to proxy for this effect: the number of intermediate processing facilities for industrial waste per capita at the prefectural level, the number of landfill sites for hazardous waste per capita at the municipality level, and a dummy variable for industrial-waste landfill sites managed by public-sector entities at the municipality level. Intermediate processing facilities and hazardous-waste facilities are typically both unwelcome and face significant public opposition by local communities. Public opposition negatively affects site location for two reasons: (1) transaction costs increase for waste-management companies that need to negotiate with inhabitants, and (2) opportunity costs also increase as the construction and operation of a site are delayed. Thus, waste-management companies tend to locate landfill sites in areas where construction is easy—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 ultimate output of these intermediate facilities is waste that requires a final landfill. A waste-management company often faces difficulties finding a suitable location for hazardous-waste facilities because opposition from residents can be even stronger than for an industrial-waste facility. Thus, a high number of other waste-related facilities is expected to increase the number of private industrial-waste landfill sites per capita in a 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 request to prefectural governments for information disclosure.

In contrast to intermediate waste-processing facilities and hazardous-waste facilities, industrial-waste landfill sites managed by the public sector are expected to reduce the concentration of private landfill sites within a municipality. Hence, to facilitate acceptance of new facilities, some prefectural and municipal governments have directly participated in the construction of industrial-waste landfill sites. The motivation for this involvement is to reduce objections from residents who may distrust private companies due to their pursuit of economic returns. We can expect landfill sites operated by the public sector to substitute for landfill sites managed by private companies. The location data for these public industrial-waste landfill sites are also obtained from the disclosure requests mentioned above.

In addition to the existence of other waste-related facilities, we incorporate the capacity of landfill sites at the regional level in the estimation models. In areas with large residual capacity of landfill sites, the demand for waste disposal might be lower.

Regional characteristics

The characteristics of municipalities include the unemployment rate, the percentage of manufacturing workers, the percentage of habitable area, and the location of international ports. The unemployment variable captures the environmental justice aspect of locating waste-management facilities. This variable allows us to test the hypothesis that industrial-waste landfill sites might be spatially concentrated in municipalities with more disadvantaged populations. Laurian and Funderburg (2014) found that towns in France with large vulnerable populations are more likely to host construction of waste incineration facilities. A municipality with a higher number of manufacturing workers is more likely to support landfill site locations because they are well aware of the need for industrial-waste disposal facilities. We consider groundwater usage to examine whether a site location is influenced by the perceived risk of groundwater contamination. The percentage of habitable area captures the potential residential area. Municipalities with a larger habitable area have less potential for site location. The municipalities with international ports may have fewer landfill sites because of a greater ability to export waste products.

The unemployment rate, manufacturing workers, and habitable area data have been taken at the municipality level and drawn from the 1990 and 2010 National Census (Japanese Ministry of Internal Affairs and Communications, respective years). Data on groundwater usage at the prefectural level are drawn from the Survey on the Usage of Groundwater for Agriculture in 1991 and 2011 (Japanese Ministry of Agriculture, Forestry and Fisheries, respective years). Data on international ports have been derived from the Geographic Information Systems (GIS) database of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (2019).

Policies

The last factor considered are the policies implemented by prefectural-level governments. In this study, we focus on the impact of industrial-waste taxation and waste-trade restrictions. Sasao (2014a, 2014b) examined the effects of these policy instruments on waste generation and transfer. He found that industrial-waste taxes in Japan have minimal effects on reducing the amount of waste destined for landfill sites, while waste-trade restrictions in destination prefectures decrease the waste inflow to landfill sites. The introduction of an industrial-waste tax and waste-trade restrictions by some prefectural governments decreases the demand for waste-landfill services and might eventually affect location decisions by encouraging the avoidance of prefectures with stricter regulations. We use two dummy variables to indicate the introduction of an industrial-waste tax and waste-trade restrictions.[6] Because the first introduction of an industrial-waste tax traces back to 2002, we include the industrial-waste tax variable only in the 2012 model. In addition to these policies, we estimate the effect of environmental regulation by including the share of prefectural nature conservation area in the municipality's total area. Municipalities with larger nature conservation areas have less available land for construction of landfill sites.

Data for the industrial-waste tax are drawn from the survey report on the state of industrial-waste tax (Hiroshima Prefecture, 2011). The data for waste-trade restrictions are drawn from the survey report on the administration of industrial waste (Japan Leasing Association, 2015). Data on prefectural nature conservation areas are obtained from the Geographic Information Systems (GIS) database (Japanese Ministry of Land, Infrastructure, Transport and Tourism,

[6] Because all prefectures apply the same tax rate, the tax rate cannot be used as an explanatory variable.

2019). The summary statistics are presented in Table 2. The average number of private landfill sites for industrial waste per 10,000 residents increased from 0.156 in 1992 to 0.168 in 2012, and the standard deviation increased from 0.524 in 1992 to 0.588 in 2012. The data's correlation matrix is shown in Appendix B.

<Table 2>

5. Results

5.1 Cross-sectional analysis of landfill site locations

To compare the factors that affect the location of waste landfill sites in 1992 and 2012, we estimate models that consider the number of industrial-waste landfill sites per capita in each year as the dependent variable. The results of the negative binomial and Poisson models are presented in Tables 3 and 4, respectively. Considering the results of the likelihood-ratio test for $\alpha = 0$, which means absence of over-dispersion, we focus on the result of the negative binomial model.

<Table 3>

<Table 4>

The location structure of landfill sites 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 coefficients on the amount of industrial waste are positive and statistically significant, in line with our expectation. This result shows that the location of industrial-waste landfill sites is sensitive to the regional demand for a waste landfill. The coefficients on land price are statistically significant and negative in both the 1992 and 2012 models. Interestingly, the coefficient on land price in the 2012 model is larger than that in the 1992 model. The manufacturing revenue coefficients are positive, but not statistically significant in either year. In summary, these results are consistent with the view that economic factors were significant determinants for the spatial concentration of landfill sites in these two decades.

The number of hazardous-waste landfill sites per capita is positive and significant both in 1992 and in 2012. A larger number of waste-related facilities is associated with a larger number of industrial-waste landfill sites, in line with the findings by Ishimura and Takeuchi (2017). In addition, the coefficient on the number of intermediate processing facilities for industrial waste per capita is positive and statistically significant both in 1992 and in 2012. These results suggest that industrial-waste landfill sites tend to be located in areas where transaction and opportunity costs are lower, such as areas with existing waste-related facilities. The coefficients on publicly supported landfill sites are not statistically significant. The residual capacity of landfill sites is negative and statistically significant in simpler models both in 1992 and in 2012. Although the result suggests that waste disposal firms tend to avoid areas with higher stock levels when locating landfill sites, the coefficients are not significant in models with more added control variables.

Regarding the impact of regional characteristics, the coefficient on the unemployment variable is negative and statistically significant in 1992, in contrast with the findings of Laurian and Funderburg (2014). In the 2012 model, the coefficient on the unemployment variable is negative but not statistically significant. Thus, our estimation results indicate that Japanese municipality-level data do not support the environmental justice hypothesis. The amount of groundwater usage is statistically significant and negative in the 1992 model. This result suggests that high dependence on groundwater relates to a high probability of health damage by groundwater pollution, which makes these municipalities reluctant to host landfill sites. In the 2012 model, the coefficient on groundwater dependence is negative but not statistically significant. The habitable area and locations of international ports are statistically insignificant in most of our estimations.

The coefficients on industrial-waste tax and trade restrictions are not statistically significant, suggesting that these policy instruments do not affect the location of landfill sites in the period analyzed. This result is in contrast with Sasao (2014b), who found that waste-trade restrictions have an impact on waste inflow. The nature reserve variable is also not statistically significant. However, polices may potentially be endogenous. Prefectural governments might introduce these policies when there is a high number of sites in their administrative area. Thus, we address this issue in the next section using new landfill site openings and lagged explanatory variables.

5.2 Panel data analysis of new landfill site openings

In this subsection, we examine the effect of local government policies on landfill site location decisions using the incremental number of landfill sites per capita as the dependent variable. We address the possible endogeneity of policy variables and the land price variable by using their lagged values in the estimation. We use municipal-level panel data from 1992 to

2012 and 31,840 observations (which correspond to 1,592 municipalities and 20 years). All estimations are based on panel negative binomial and Poisson models.[7]

Table 5 and Table 6 reports the estimation results including a pooled model, a random-effects model, and a prefecture fixed-effects model for the number of newly constructed sites per capita. All explanatory variables are lagged by one year. The estimation results using year dummy variables are reported in the fourth to sixth columns. We find that the coefficients on policy instruments are negative and statistically significant in models without year dummies. These results indicate that implementation of an industrial-waste tax and trade restrictions on industrial-waste shipments decreases the number of private landfill sites constructed. For instance, the coefficient in the second column of Table 5 implies that municipalities with waste-trade restrictions have 0.424 fewer newly opened sites than prefectures without restrictions. Similarly, the industrial-waste tax decreases the number of new landfill site openings by 0.768 in municipalities that introduce such taxes. Because enforcement of local regulations affects disposal prices and thereby the demand for waste disposal, new construction is attracted to areas

[7] Because a number of municipalities have not had new landfill sites for 20 years, many municipalities would be dropped from the sample if a municipality fixed-effects model was used. Standard errors are clustered by prefecture. Also, because 100 municipalities (three prefectures) do not have new landfill sites for 20 years, 2,000 observations were dropped from the fixed effect model. Thus, we dropped these 2,000 observations from all models to compare results across the different specification.

with lax regulations. On the other hand, these policy variables are not statistically significant in many models with year dummies. Because many prefectures introduced policies during similar periods, policy effects are difficult to capture using models with year dummies.

The coefficients on land price are negative and statistically significant. This result implies that higher construction costs reduce new landfill site openings. Along with the positive and statistically significant coefficients on the amount of industrial waste and the manufacturing revenue, the findings support the hypothesis that economic factors play a critical role in determining the number of new landfill site openings. In contrast with the estimation results in the previous section, the estimated coefficients on the number of intermediate sites are negative and statistically significant, which suggests that waste management companies are likely to avoid construction of new landfill sites in areas where recycling facilities are located. The reason may be a steady increase in recycling in Japan during the two decades studied. In 2012, the industrial-waste recycling rate in Japan increased to 55%. Because intermediate processing facilities reduce the amount of waste for final disposal, the demand for disposal services in landfill sites will be low in areas that have a larger number of such facilities. The estimated coefficients on the amount of groundwater usage are statistically significant and positive, in contrast with the results in Table 3. These results indicate that new landfill sites are located in areas with higher dependence on groundwater. One reason for these results might be the stricter-than-ever regulations on the construction of landfill sites over the past two decades. After the revisions of the Waste Management Law in 1997 and 1998, the standards for facility structures and operations of landfill sites were elevated. As a result, waste management companies may opt for constructing facilities in areas characterized by a higher dependence on groundwater, as long as the standards for facility structures fulfill the strict conditions required by law.[8]

<Table 5>

<Table 6>

6. Conclusions

[8] Although revisions of the Waste Management Law in 1997 and 1998 considerably reduced the total number of newly opened landfill sites, the impact of these revisions is common to all landfill sites in Japan. Therefore, it is not possible to analyze the different impacts of these revisions in each municipality.

This study explored the mechanisms behind the concentration of private industrial-waste landfill sites. The empirical results suggest a spatial concentration of landfill sites existed in Japan over the two decades studied. Moreover, we found that the determinants of landfill site location have not changed over time. Economic factors such as land prices play a significant role in determining the location of private landfill sites. In addition, our empirical results indicate that implementation of policies by prefectural governments, such as an industrial-waste tax and trade restrictions, could have reduced the number of newly opened landfill sites. These findings suggest that the theory of spatial competition between companies can be applied to facilities dealing with "bads."

Our results offer several implications for policies regarding the location of facilities undesirable to local communities. As suggested by our findings, the locational concentration of private landfill sites is likely driven by economic considerations. Nevertheless, we do not observe potentially negative consequences, such as concentration in areas with higher unemployment or higher shares of nature reserves. From the viewpoint of social welfare, it might be better to concentrate undesirable facilities in several areas rather than having them scattered across the entire area. However, in general, local governments and residents are not comfortable with nearby concentrations of landfill sites, which may trigger NIMBY (not-inmy-backyard) reactions. Local policy instruments may reduce the number of sites in a particular area but may also result in shifting site locations to neighboring municipalities. In that sense, concentration of landfill sites in some areas may be attributed to the uncoordinated regulations of local administrations. Policy coordination among local governments is important for mitigating excessive concentration of landfill sites and their negative consequences.

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 studies have suggested, a negative external economy of a waste-related facility causes land prices near the site to decline. This decline may cause a further concentration of unwanted facilities attracted by low land prices. A possible extension of this study is to address 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.

Baden, B. M., Coursey, D.L., 2002. The locality of waste sites within the city of Chicago: A demographic, social, and economic analysis. Resource and Energy Economics 24, 53-59.

Baggs, J., 2009. International trade in hazardous waste. Review of International Economics 17 (1), 1-16.

Cohen, J. J., Moeltner, K., Reichl, J., Schmidthaler, M., 2016. Linking the value of energy reliability to the acceptance of energy infrastructure: Evidence from the EU. Resource and Energy Economics 45, 124-143.

Currie, J., Davis, L., Greenstone, M., Walker, R., 2013. Do Housing Prices Reflect Environmental Health Risks? Evidence from More Than 1600 Toxic Plant

Openings and Closings. US Census Bureau Discussion Papers, Center for Economic Studies CES 13-14.

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.

Galka, M., 2016. What does New York do with all its trash? One city's waste–in numbers. The Guardian, 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)

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 state of local governments implementing industrial waste tax], in Japanese. https://www.pref.hiroshima.lg.jp/uploaded/attachment/41035.pdf (accessed on January 29, 2018)

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

Ichinose, D., Yamamoto, M., 2011. On the relationship between the provision of waste management service and illegal dumping. Resource and Energy Economics 33, 79-93.

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 the policy for industrial waste] Tokyo, Japan, in Japanese.

Japanese Ministry of Agriculture, Forestry and Fisheries, 1991 and 2011. Nougyouyouchikasui no riyoujittai: dai 5 kai nougyouyouchikacui no riyoujittaichousa no gaiyou [The usage of groundwater for agriculture: a summary of the third, fourth, 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 Economy, Trade, and Industry, 1992 and 2012. Heisei 4 nendo and 24 nen kougyou toukei chousa [The 1992 and 2012 census of manufacturers], Tokyo, Japan, in Japanese.

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

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

Japanese Ministry of the Environment, 2014. History and Current State of Waste Management in Japan, Tokyo, Japan. https://www.env.go.jp/en/recycle/smcs/attach/hcswm.pdf (accessed on March 29, 2019)

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

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

Japanese Ministry of Land, Infrastructure, Transport and Tourism, 2015. Kokudosuchijouhou chika koji data [Data on land prices from the Geographic Information Systems (GIS) database], in Japanese. http://nlftp.mlit.go.jp (accessed April 27, 2018)

Japanese Ministry of Land, Infrastructure, Transport and Tourism, 2019. Kowan data [Data on nature reserve area from the Geographic Information Systems (GIS) database], in Japanese. http://nlftp.mlit.go.jp (accessed July 8, 2019)

Japanese Ministry of Land, Infrastructure, Transport and Tourism, 2019. Shizen hozenchiki data [Data on nature reserve area from the Geographic Information Systems (GIS) database], in Japanese. http://nlftp.mlit.go.jp (accessed March 7, 2019)

Kellenberg, D., 2012. Trading waste. Journal of Environmental Economics and Management 64 (1), 68-87.

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.

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.

Murata, T., 1998. Sangyo haikibutsu shori wo meguru houseido no genjou to kadai [The present state of Waste Management Law and its problem to be solved]. Haikibutsu Gakkai Shi [Waste Management Research] 9(6), 424-433, in Japanese.

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

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.

Taylor, L. O., Phaneuf, D. J., Liu, X., 2016. Disentangling property value impacts of environmental contamination from locally undesirable land uses: Implications for measuring post-cleanup stigma, Journal of Urban Economics 93, 85-98.

Ueta, K., Kitagawa, S., 2001. Junkangata Shakai Handobukku [Handbook for the Sound Material-Cycle Society], Yuhikaku Publishing, in Japanese.

Walsh, P., Mui, P., 2017. Contaminated sites and information in hedonic models: An analysis of a NJ property disclosure law, Resource and Energy Economics 50, 1-14.

Table 1: The Global Moran's I statistic from 1992 to 2012

Year	Moran's I	Standard Deviation	p-value
1992	0.144	9.363	0.000
1993	0.134	8.652	0.000
1994	0.137	8.843	0.000
1995	0.157	10.070	0.000
1996	0.182	11.693	0.000
1997	0.211	13.511	0.000
1998	0.215	13.759	0.000
1999	0.210	13.461	0.000
2000	0.211	13.511	0.000
2001	0.222	14.234	0.000
2002	0.236	15.113	0.000
2003	0.230	14.712	0.000
2004	0.230	14.748	0.000
2005	0.217	13.882	0.000
2006	0.254	16.307	0.000
2007	0.254	16.329	0.000
2008	0.237	15.222	0.000
2009	0.238	15.312	0.000
2010	0.239	15.401	0.000
2011	0.235	15.051	0.000
2012	0.202	12.921	0.000

Table 2: Descriptive statistics

		1992				2012			
	Unit	Mean	Min	Max	SD	Mean	Min	Max	SD
Private landfill sites for industrial waste	sites/10,000 persons, municipal level	0.154	0.000	10.402	0.523	0.168	0.000	7.924	0.588
Landfill sites for hazardous waste	sites/10,000 persons, municipal level	0.032	0.000	2.160	0.151	0.060	0.000	8.032	0.370
Intermediate site for industrial waste	sites/10,000 persons, prefectural level	0.964	0.126	2.455	0.510	1.886	0.229	4.793	0.865
Publicly supported landfill site	1 = yes, 0 = otherwise, municipal level	0.045	0.000	1.000	0.207	0.046	0.000	1.000	0.210
Residual capacity	million m^3, regional level	20.617	10.746	38.022	8.649	20.688	8.090	37.500	8.618
Unemployment rate	%, municipal level	2.636	0.000	14.200	1.427	6.327	0.000	22.700	2.123
Manufacturing workers	%, municipal level	9.589	0.000	77.617	6.967	7.088	0.000	70.630	6.316
Amount of groundwater	million m^3, prefectural level	78.432	1.664	1187.112	150.818	61.826	2.098	690.866	100.916
Habitable area	10%, municipal level	4.806	0.260	10.000	2.973	4.859	0.240	10.000	2.986
International port	1 = yes, 0 = otherwise, municipal level	0.067	0.000	1.000	0.250	0.067	0.000	1.000	0.251
Amount of industrial waste	10 million tons, prefectural level	19.495	0.000	876.773	51.416	17.051	0.000	1208.886	48.053
Total manufacturing revenue	10 billion yen, municipal level	1.197	0.176	3.303	0.975	1.163	0.113	3.612	1.022
Land price	10,000 yen, municipal level	13.908	0.178	1325.364	61.914	4.450	0.170	208.500	8.905
Nature reserve area	%, municipal level	0.251	0.000	51.284	1.811	0.255	0.000	51.284	1.812
Waste-trade restriction	1 = yes, 0 = otherwise, prefectural level	0.212	0.000	1.000	0.409	0.715	0.000	1.000	0.452
Industrial-waste taxation	1 = yes, 0 = otherwise, prefectural level	–	–	–	–	0.570	0.000	1.000	0.495

Table 3: Estimation results: Negative binomial model

	1992			2012		
	Coef.	*Coef.*	*Coef.*	*Coef.*	*Coef.*	*Coef.*
Disposal site for hazardous waste	1.099 ***	0.786 ***	0.757 **	0.486 ***	0.316 ***	0.309 ***
	(0.306)	(0.295)	(0.295)	(0.122)	(0.099)	(0.099)
Intermediate site for industrial waste	0.026	0.291 *	0.320 *	0.567 ***	0.490 ***	0.423 ***
	(0.154)	(0.173)	(0.174)	(0.097)	(0.115)	(0.135)
Publicly supported landfill site	0.237	0.101	0.107	0.417	0.240	0.219
	(0.319)	(0.335)	(0.335)	(0.283)	(0.286)	(0.286)
Capacity	-0.039 ***	-0.008	-0.010	-0.058 ***	0.003	-0.001
	(0.009)	(0.010)	(0.010)	(0.009)	(0.011)	(0.011)
Unemployment	-0.239 ***	-0.133 **	-0.125 **	-0.072 **	-0.032	-0.032
	(0.065)	(0.059)	(0.060)	(0.034)	(0.031)	(0.032)
Manufacturing workers	-0.019 *	-0.005	-0.003	-0.028 *	-0.004	-0.003
	(0.011)	(0.011)	(0.011)	(0.014)	(0.014)	(0.013)
Amount of groundwater	-0.003 **	-0.002 **	-0.002 **	-0.001	-0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Habitable area	-0.031	0.030	0.027	-0.065 **	-0.019	-0.023
	(0.026)	(0.029)	(0.029)	(0.029)	(0.032)	(0.032)
International port	0.157	0.308	0.290	-0.282	-0.083	-0.105
	(0.290)	(0.290)	(0.290)	(0.304)	(0.311)	(0.311)
Total manufacturing revenue		0.000	0.000		0.001	0.001
		(0.002)	(0.002)		(0.002)	(0.002)
Amount of industrial waste		0.469 ***	0.498 ***		0.536 ***	0.490 ***
		(0.073)	(0.078)		(0.074)	(0.083)
Land price		-0.076 ***	-0.074 ***		-0.168 ***	-0.152 ***
		(0.016)	(0.016)		(0.049)	(0.050)
Nature reserve			-0.060			-0.149
			(0.075)			(0.129)
Waste trade restriction			0.246			0.130
			(0.176)			(0.282)
Industrial waste tax						0.223
						(0.216)
Intercept	-0.184	-1.894 ***	-1.996 ***	-1.105 ***	-3.045 ***	-3.024 ***
	(0.273)	(0.359)	(0.376)	(0.364)	(0.513)	(0.548)
α	0.732 ***	0.568 ***	0.563 ***	0.970 ***	0.688 ***	0.680 ***
	(0.163)	(0.143)	(0.142)	(0.185)	(0.153)	(0.152)
Obs.	1,692	1,692	1,692	1,692	1,692	1,692
Log likelihood	-726.919	-686.272	-684.902	-706.027	-659.444	-657.782
AIC	1,475.837	1,400.543	1,401.803	1,434.055	1,346.889	1,349.564

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

Table 4: Estimation results: Poisson model

	1992			2012		
	Coef.	*Coef.*	*Coef.*	*Coef.*	*Coef.*	*Coef.*
Disposal site for hazardous waste	0.946 ***	0.701 ***	0.683 ***	0.276 ***	0.211 ***	0.208 ***
	(0.236)	(0.250)	(0.251)	(0.046)	(0.047)	(0.048)
Intermediate site for industrial waste	0.007	0.297 *	0.326 *	0.528 ***	0.484 ***	0.418 ***
	(0.146)	(0.167)	(0.167)	(0.081)	(0.106)	(0.125)
Publicly supported landfill site	0.225	0.028	0.033	0.437 *	0.289	0.269
	(0.297)	(0.317)	(0.318)	(0.238)	(0.240)	(0.240)
Capacity	-0.039 ***	-0.008	-0.010	-0.070 ***	0.002	-0.002
	(0.009)	(0.009)	(0.010)	(0.009)	(0.010)	(0.011)
Unemployment	-0.240 ***	-0.126 **	-0.119 **	-0.077 **	-0.028	-0.028
	(0.061)	(0.055)	(0.055)	(0.030)	(0.026)	(0.027)
Manufacturing workers	-0.021 **	-0.008	-0.006	-0.031 **	-0.005	-0.004
	(0.011)	(0.010)	(0.010)	(0.014)	(0.013)	(0.013)
Amount of groundwater	-0.003 **	-0.002 **	-0.002 **	-0.001	-0.002	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Habitable area	-0.025	0.032	0.028	-0.055 **	-0.005	-0.009
	(0.024)	(0.027)	(0.027)	(0.026)	(0.028)	(0.029)
International port	0.146	0.273	0.258	-0.335	-0.156	-0.177
	(0.272)	(0.269)	(0.269)	(0.276)	(0.282)	(0.282)
Total manufacturing revenue		0.000	0.000		0.001	0.001
		(0.002)	(0.002)		(0.002)	(0.002)
Amount of industrial waste		0.467 ***	0.497 ***		0.545 ***	0.496 ***
		(0.069)	(0.073)		(0.069)	(0.078)
Land price		-0.076 ***	-0.074 ***		-0.176 ***	-0.159 ***
		(0.015)	(0.015)		(0.048)	(0.048)
Nature reserve			-0.061			-0.148
			(0.074)			(0.122)
Waste trade restriction			0.247			0.148
			(0.168)			(0.273)
Industrial waste tax						0.230
						(0.206)
Intercept	-0.139	-1.880 ***	-1.979 ***	-0.771 **	-3.072 ***	-3.075 ***
	(0.257)	(0.341)	(0.357)	(0.308)	(0.482)	(0.520)
Obs.	1,692	1,692	1,692	1,692	1,692	1,692
Log likelihood	-747.405	-701.394	-699.883	-738.164	-680.730	-678.800
AIC	1,514.810	1,428.788	1,429.767	1,434.055	1,387.460	1,389.598

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

Table 5: Estimation results: New openings of landfill sites (Negative binomial model)

	Pooled	Random-Effects	Fixed-Effects	Pooled	Random-Effects	Fixed-Effects
	(1)	(2)	(3)	(4)	(5)	(6)
	Coef.	*Coef.*	*Coef.*	*Coef.*	*Coef.*	*Coef.*
Disposal site for hazardous waste	1.043 ***	0.548 ***	0.767 ***	0.951 ***	0.594 ***	0.821 ***
	(0.174)	(0.145)	(0.122)	(0.149)	(0.140)	(0.119)
Intermediate site for industrial waste	-0.007 ***	-0.018 ***	-0.018 ***	-0.004 ***	-0.012 ***	-0.013 ***
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Publicly supported landfill site	0.188	0.548 ***	0.396 ***	0.404 ***	0.693 ***	0.442 ***
	(0.162)	(0.196)	(0.131)	(0.147)	(0.203)	(0.133)
Capacity	0.007	0.028 ***	0.032 ***	-0.012	0.011	0.021 **
	(0.017)	(0.008)	(0.008)	(0.015)	(0.008)	(0.008)
Unemployment	-0.251 ***	-0.254 ***	-0.249 ***	-0.082	-0.009	-0.099 ***
	(0.078)	(0.037)	(0.033)	(0.075)	(0.041)	(0.035)
Manufacturing workers	-0.047 ***	-0.031 **	-0.006	-0.045 ***	-0.038 ***	-0.009
	(0.018)	(0.014)	(0.009)	(0.016)	(0.014)	(0.010)
Amount of groundwater	0.002	0.018 ***	0.012 ***	0.004	0.016 ***	0.011 ***
	(0.006)	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)
Habitable area	-0.093 *	-0.006 **	0.012	-0.073 *	-0.003	0.021
	(0.047)	(0.003)	(0.020)	(0.043)	(0.003)	(0.020)
International port	0.677 **	1.745 ***	0.875 ***	0.675 **	1.534 ***	0.794 ***
	(0.264)	(0.207)	(0.115)	(0.292)	(0.209)	(0.116)
Total manufacturing revenue	0.001	0.015 ***	0.003 ***	0.003	0.018 ***	0.003 ***
	(0.001)	(0.002)	(0.000)	(0.002)	(0.003)	(0.000)
Amount of industrial waste	0.623 ***	0.373 ***	0.322 ***	0.692 ***	0.343 ***	0.324 ***
	(0.117)	(0.063)	(0.056)	(0.089)	(0.063)	(0.057)
Land price	-0.144 ***	-0.032 ***	0.003	-0.146 ***	-0.048 ***	-0.003
	(0.027)	(0.010)	(0.003)	(0.024)	(0.011)	(0.007)
Nature reserve	-0.175 *	-0.016	0.011	-0.121	-0.024	0.020
	(0.092)	(0.100)	(0.053)	(0.092)	(0.098)	(0.053)
Waste trade restriction	-0.605 *	-0.424 ***	-0.361 ***	-0.270	-0.044	0.001
	(0.315)	(0.136)	(0.138)	(0.287)	(0.141)	(0.145)
Industrial waste tax	-1.225 ***	-0.768 ***	-0.748 ***	-0.155	-0.372	-0.540 **
	(0.307)	(0.199)	(0.190)	(0.375)	(0.252)	(0.247)
Intercept	-1.226 **	-2.926 ***	-4.031 ***	-0.543	-2.771 ***	-3.820 ***
	(0.527)	(0.308)	(0.280)	(0.477)	(0.315)	(0.290)
α	67.578 ***			48.194 ***		
	(9.320)			(6.255)		
Year Dummy	NO	NO	NO	YES	YES	YES
Obs.	31,840	31,840	31,840	31,840	31,840	31,840
Log likelihood	-3,568.991	-3,289.798	-3,123.612	-3,419.201	-3,188.669	-3,042.876
Wald χ2	856.180	374.770	463.040	3,056.090	539.940	614.090
AIC	7,171.982	6,615.595	6,279.223	6,910.402	6,451.337	6,155.751

Note: Standard errors in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. The dependent variable is the number of newly opened industrial-waste disposal sites per 100,000 residents. The values of intermediate site for industrial waste, amount of groundwater, and habitable area are divided by ten.

Table 6: Estimation results: New openings of landfill sites (Poisson model)

	Pooled	Random-Effects	Fixed-Effects	Pooled	Random-Effects	Fixed-Effects
	(1)	(2)	(3)	(4)	(5)	(6)
	Coef.	*Coef.*	*Coef.*	*Coef.*	*Coef.*	*Coef.*
Disposal site for hazardous waste	0.481 ***	-0.182 ***	0.483 ***	0.554 ***	-0.029	0.527 ***
	(0.029)	(0.055)	(0.031)	(0.027)	(0.053)	(0.032)
Intermediate site for industrial waste	-0.004 ***	-0.004 ***	-0.002 ***	-0.001 **	-0.001 ***	-0.001 ***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Publicly supported landfill site	0.028	-0.097	0.125	0.227 **	0.331 **	0.196 **
	(0.081)	(0.138)	(0.088)	(0.092)	(0.140)	(0.089)
Capacity	0.002	0.021 ***	0.043 ***	-0.007	0.009	0.006
	(0.018)	(0.007)	(0.008)	(0.018)	(0.007)	(0.010)
Unemployment	-0.307 ***	-0.398 ***	-0.276 ***	-0.132	-0.225 ***	-0.217 ***
	(0.085)	(0.028)	(0.018)	(0.118)	(0.035)	(0.020)
Manufacturing workers	-0.028 *	0.074 ***	0.008 *	-0.030 *	0.021	0.001
	(0.015)	(0.014)	(0.005)	(0.017)	(0.015)	(0.005)
Amount of groundwater	-0.003	0.003	0.038 ***	-0.001	0.002	0.016
	(0.020)	(0.006)	(0.013)	(0.012)	(0.005)	(0.013)
Habitable area	0.003	-0.167 ***	0.034 ***	0.025	-0.098 ***	0.044 ***
	(0.040)	(0.038)	(0.010)	(0.038)	(0.037)	(0.010)
Port	0.247	0.703 *	-0.117	0.158	0.709 **	-0.130
	(0.233)	(0.414)	(0.098)	(0.180)	(0.359)	(0.099)
Total manufacturing revenue	0.001	-0.006 ***	0.001 *	0.001	-0.003	0.001 *
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Amount of industrial waste	0.615 ***	0.106	-1.191 ***	0.664 ***	0.622 ***	0.651 ***
	(0.098)	(0.069)	(0.098)	(0.099)	(0.075)	(0.153)
Land price	-0.167 ***	-0.087 ***	-0.075 ***	-0.169 ***	-0.115 ***	-0.092 ***
	(0.040)	(0.021)	(0.013)	(0.030)	(0.019)	(0.013)
Nature reserve	-0.113	-0.268 *	0.001	-0.088	-0.195	0.008
	(0.083)	(0.147)	(0.045)	(0.081)	(0.136)	(0.044)
Waste trade restriction	-0.663 *	-1.007 ***	-1.086 ***	-0.012	-0.194	-0.280
	(0.347)	(0.118)	(0.131)	(0.314)	(0.171)	(0.183)
Industrial waste tax	-0.991 ***	-0.512 ***	-1.012 ***	-0.238	-0.245 *	-0.229
	(0.236)	(0.117)	(0.114)	(0.342)	(0.126)	(0.152)
Intercept	-1.411 ***	-0.543 *		-1.208 **	-1.231 ***	
	(0.494)	(0.315)		(0.469)	(0.303)	
α		13.055 ***			9.798 ***	
		(1.021)			(0.760)	
Year Dummy	NO	NO	NO	YES	YES	YES
Obs.	31,840	31,840	31,840	31,840	31,840	31,840
Log likelihood	-9,715.065	-7,074.577	-8,906.580	-9,003.050	-6,573.308	-8,456.496
Wald χ2	3175.030	932.520	1293.800	7,425.880	1639.250	1811.170
AIC	19,462.129	14,183.154	17,843.159	18,076.099	13,218.617	16,980.993

Note: Standard errors in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. The dependent variable is the number of newly opened industrial-waste disposal sites per 100,000 residents. The values of intermediate site for industrial waste, amount of groundwater, and habitable area are divided by ten.

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

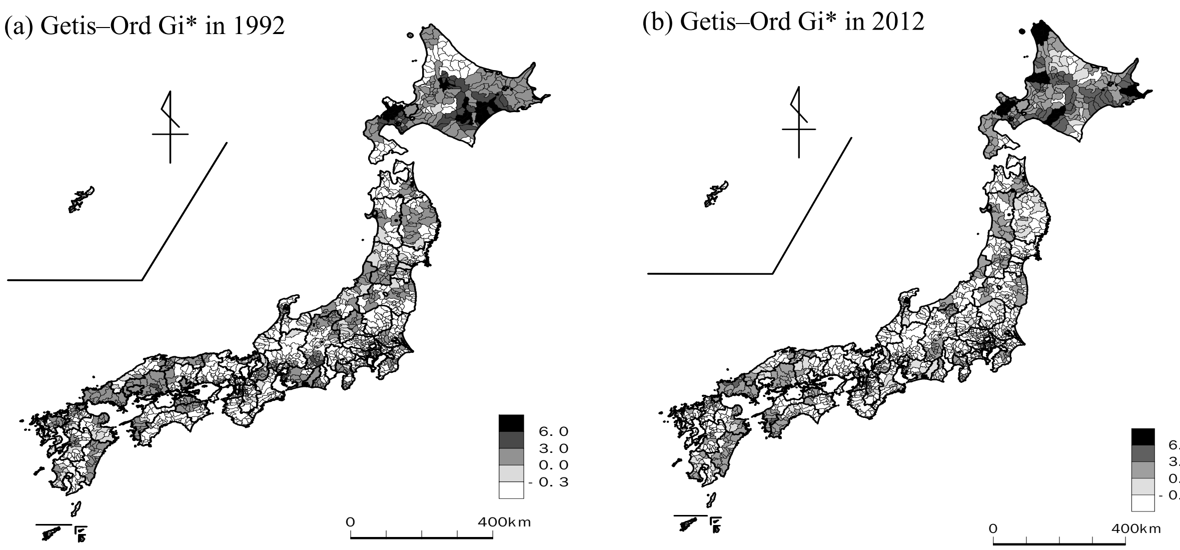
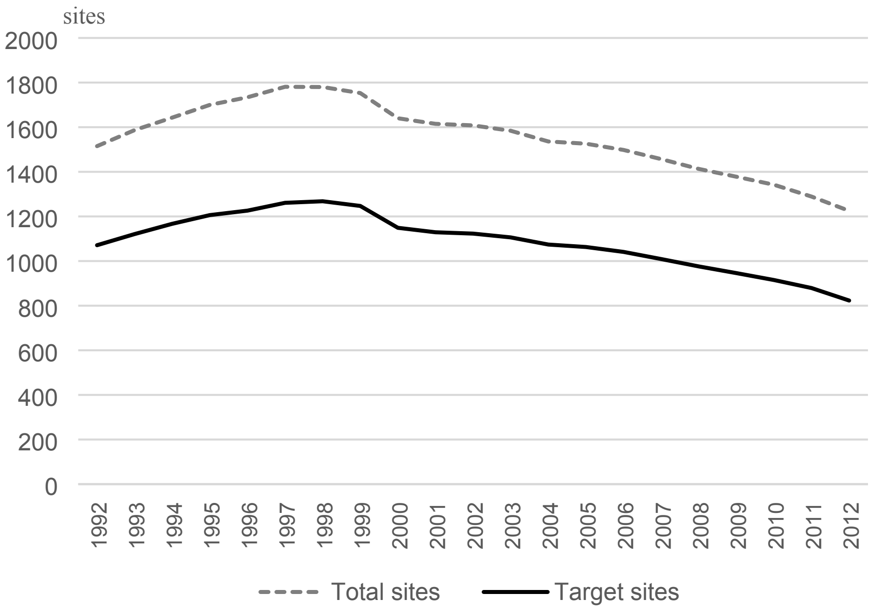


Figure 2: Number of operating landfill sites

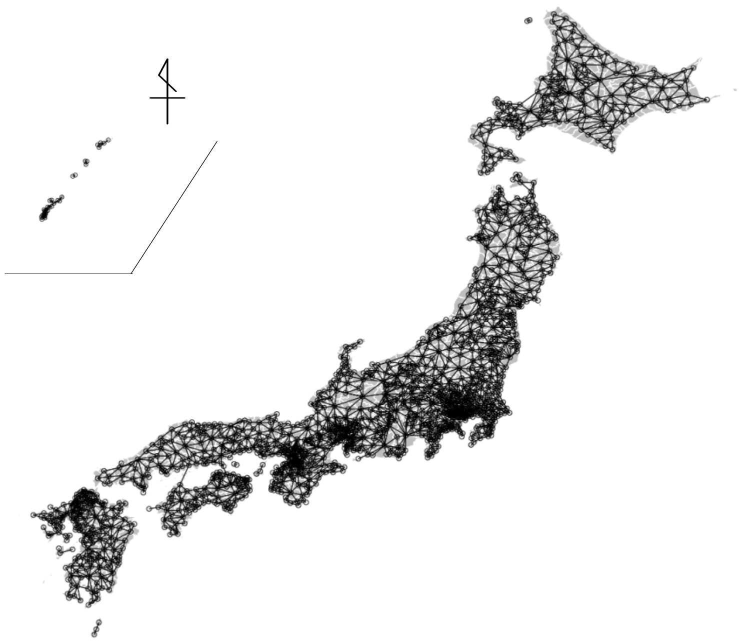


Note: Privately managed sites for industrial waste are included in target sites. In addition, privately managed sites for toxic industrial waste and publicly supported sites are included in total sites.

Appendix A

Figure A shows the neighboring relationships between municipalities. It is based on the spatial weight matrix W and uses queen-type contiguity, which considers any two local municipalities as neighbors if they share any boundary point. We do not include municipalities with no neighbors in the analysis.

Figure A: Neighboring relationships between municipalities



Appendix B

Table B (a): Correlation matrix in 1992

	Hazard	Inter	Public	Capacity	Unemp	Manu	Water	Habitable	Port	Indus	Waste	Landprice	Nature	Trade
Hazard	1													
Inter	0.086	1												
Public	0.099	0.060	1											
Capacity	-0.024	-0.077	0.075	1										
Unemp	0.015	-0.239	0.040	0.209	1									
Manu	0.089	0.273	0.061	-0.013	-0.202	1								
Water	-0.035	0.142	-0.036	0.012	-0.099	0.119	1							
Habitable	0.019	-0.040	0.019	0.130	0.151	0.215	0.113	1						
Port	0.021	0.060	0.239	0.015	0.191	-0.044	-0.050	0.010	1					
Indus	0.017	0.069	0.305	0.076	0.050	0.197	0.020	0.231	0.320	1				
Waste	-0.010	-0.276	0.058	-0.159	-0.020	-0.116	-0.120	0.218	-0.034	0.130	1			
Landprice	-0.029	-0.154	0.012	0.026	0.036	0.128	-0.048	0.241	0.057	0.186	0.234	1		
Nature	-0.019	0.008	-0.023	-0.070	-0.030	0.049	-0.001	-0.054	-0.004	0.018	0.027	-0.009	1	
Trade	0.019	0.016	-0.043	-0.024	-0.122	0.008	0.203	-0.055	0.018	-0.031	-0.179	-0.061	-0.002	1

Table B (b): Correlation matrix in 2012

	Hazard	Inter	Public	Capacity	Unemp	Manu	Water	Habitable	Port	Indus	Waste	Landprice	Nature	Trade	Tax
Hazard	1														
Inter	0.077	1													
Public	-0.015	0.027	1												
Capacity	-0.088	-0.038	-0.030	1											
Unemp	-0.067	-0.085	-0.027	0.210	1										
Manu	-0.023	-0.002	0.067	0.042	-0.078	1									
Water	-0.042	-0.113	-0.026	0.093	0.032	0.088	1								
Habitable	-0.062	-0.418	-0.022	0.038	0.137	0.159	0.114	1							
Port	-0.011	0.100	0.222	0.049	0.091	-0.038	-0.042	0.008	1						
Indus	-0.015	-0.111	0.221	0.002	-0.038	0.207	0.012	0.177	0.302	1					
Waste	0.141	-0.126	0.062	-0.467	-0.134	-0.178	-0.068	0.081	-0.018	0.005	1				
Landprice	-0.052	-0.417	0.004	-0.065	-0.030	-0.081	-0.080	0.403	0.033	0.129	0.145	1			
Nature	-0.016	-0.041	-0.020	-0.059	0.020	0.016	-0.021	-0.052	-0.005	0.005	0.020	0.012	1		
Trade	0.081	0.621	0.008	-0.187	-0.183	0.045	0.078	-0.286	0.060	-0.047	0.026	-0.351	-0.052	1	
Tax	0.082	0.426	0.054	0.234	0.058	-0.053	-0.150	-0.195	0.086	-0.063	0.116	-0.250	-0.048	0.230	1

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