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Environmental justice in France? A spatio-temporal analysis of incinerator location

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The concept of Environmental Justice (EJ) refers to social inequities in the distribution of environmental risks. This paper presents the first European *spatio-temporal* EJ analysis, focusing on the location of 107 waste incinerators in France since the 1960s to assess potential biases in siting decisions. It uses a spatial econometric analysis that accounts for vulnerable populations at the time unwanted land uses were sited. We find that, after controlling for a town's socio-economic characteristics and the opportunity costs represented by the demand of its neighbours, each additional 1% of a town's population that is foreign-born increased the odds that the town received an incinerator by 29%. Disproportionate siting near concentrations of immigrants thus generates environmental injustice in France.

Keywords: environmental justice; spatial econometric analysis; incinerators; France

1. Introduction

The concept of Environmental Justice (EJ), which emerged in the US in the 1980s and in Europe in the early 2000s, refers to social inequities in the distribution of environmental risks. EJ analyses typically focus on the location of polluting facilities in disadvantaged communities. A common weakness of EJ studies is their failure to control for factors that are unrelated to social disadvantages yet shape site selection decisions, such as regional demand or transportation cost-minimisation strategies. Waste facilities, for example, could be evenly arranged near employment and population centres independently of unjust decisions.

We present the first European *spatial* EJ analysis that estimates conditional probabilities of incinerator sitings based on community characteristics *at the time of the sitings*. The contributions of the paper are methodological and substantial. Incorporating controls for the optimal spatial configuration and accounting for historical socio-demographic changes, we model the location of 107 waste incinerators sited in France since the 1960s. France emphasises incineration (with associated 'renewable' energy production) as a key element of solid waste management. It has the greatest number of incinerators and the highest incineration rate of all European countries (approximately 40%). A previous cross-sectional study

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discovered that at present incinerators (and other toxic sites) are disproportionately located in disadvantaged communities (Laurian 2008a).[1] Here, we test the hypothesis that incinerators were disproportionately sited in towns with more disadvantaged populations (unemployed persons and immigrants) at the time of the siting.

The next section discusses the evolution of the EJ concept in the US and Europe, France's reliance on incineration for waste management, the health impacts of incinerators, regulatory frameworks and public opposition to incinerators. The third section presents the data and methodology used to test the hypothesised siting biases. In section four, we present the findings of the spatial and temporal econometric analysis. We conclude the discussion with the methodological contribution of our analysis and the implication of the findings for environmental policy.

2. Literature and background

Environmental Justice encompasses the distribution of risks or benefits (Cutter 1995, Lake 1996) and the mechanisms that generate and maintain injustices.[2] Early American studies (e.g. US GAO 1983, UCCCRJ 1987, Bullard 1990, 1993, Bryant and Mohai 1992) showed that minority and poor communities bear a disproportionate burden of pollution. Since the mid-1980s, increasingly comprehensive and sophisticated studies refined the measurement of inequities and investigated their causes (see Laurian 2008b for a summary). After controlling for income, studies have generally concluded that minority communities bear disproportionate risks, e.g. Bullard 1990, 1993, 1994, 1996, Bryant and Mohai 1992, Zimmerman 1993, Cutter 1995, Pollock and Elliot Vittes 1995, Arora and Cason 1996, Cutter and Solecki 1996, Heiman 1996, Boone and Modarres 1999, Morello-Frosh *et al.* 2001, Atlas 2002, Grineski *et al.* 2007; see also Mennis 2002a, 2002b, 2003, 2005 and Mennis and Jordan 2005 for refined spatial analyses, and Deka 2004, Chakraborty 2006 and Chi and Parisi 2011 for the EJ effects of transportation infrastructure.

European EJ studies reached similar conclusions (Agyeman 2002). The first British studies found that the largest factories and most carcinogenic industrial emissions in the UK are located in the most deprived areas (FoE 1999, Walker and Bickerstaff 2000, Pennycook *et al.* 2001, Brainard *et al.* 2002, Agyeman and Evans 2004). The poorest populations also live in areas with the worst air pollution (Mitchell and Dorling 2003) and the relationship between minority ethnic groups and pollution is significant even after controlling for deprivation (McLeod *et al.* 2000).

The first cross-sectional EJ study in France showed that towns with the highest proportions of immigrants are most likely to host polluted and polluting industrial facilities, even after controlling for income, population size, employment in manufacturing, and unemployment and correcting for spatial autocorrelation (Laurian 2008a).

These injustices can occur if:

(1) Disadvantaged communities are targeted because they are least likely to oppose or most willing to accept environmental risks;
(2) Little or no legal recourse is available to communities seeking to oppose or cleanup a site;[3]
(3) Inexpensive land is sought, which may be more abundant near minority or disenfranchised communities;

(4) Historical land development patterns cluster minority and poor populations near industrial activities; and
(5) Market forces disproportionately attract or retain poor and minority households in polluted areas *after* a siting (Been 1994, Been and Gupta 1997).

Conceptually, these processes are not US-specific. While the US has a unique history of racial spatial segregation, European nations also display spatial segregation and unequal social capital by class and national origin. The potential for environmental inequities by ethnicity or immigration status thus exists, but can be expected to take different forms across countries.

The existing European studies that describe environmental injustice do not investigate causal *processes*, except for Coenen and Halfacre 2003. Most have focused on class and income differentials, except for Laurian (2008a) and McLeod *et al.* (2000) who also considered immigration and ethnicity, respectively. While environmental 'racism' has not been demonstrated in Western Europe, explicit environmental discrimination against Roma populations in Eastern Europe shows that it is not a uniquely American phenomenon (Ladányi and Szelenyi 2005, Steger 2007, Harper *et al.* 2009). To begin investigating potential procedural injustice in France, we assess whether populations in towns with incinerators were disproportionately disenfranchised at the time of the siting.

2.1. Incineration in France

Metropolitan France, with a population of 63 million and a territory the size of Texas, operates 130 waste incinerators – more than all other European countries combined.[4] Its first incinerators opened in 1965 and it is now the European country with the highest incineration rate (40% of non-hazardous wastes, ADEME 2008, MDD 2010a).

Waste incineration generates slag and ashes which are high in heavy metal content as well as emissions of dioxin,[5] heavy metals, polycyclic aromatic hydrocarbons and particulate matter. Incinerators are among the leading source of dioxin emissions in North America and Western Europe (US EPA 2006). In France, a 1991 decree on combustion temperatures decreased emissions at some facilities and a 1997 directive set a maximum emission level for dioxin and furans at $0.1 ng/m^3$ for new facilities. This standard was generalised by a 2000 EU directive implemented in France in 2002.[6]

Some incinerators far exceeded these prescribed emissions limits in the late 1990s and early 2000s. For example, the Besançon incinerator emitted 16.3ng/m3 of dioxin in 1997 (Floret *et al.* 2003). In 2002, 40 incinerators violated EU standards, 13 failed to comply in 2006 (some with emissions 15 times the maximum allowed), and all complied by 2008 (Viel *et al.* 2008). Despite problems with implementation and compliance, total emissions have decreased in recent decades – even though the amount of waste incinerated has increased (INVS 2006, MDD 2010b, see Rootes 2009a about emission reductions in the US).[7]

The environmental impacts of dioxin emissions continue after compliance is achieved since airborne releases of dioxin and heavy metals remain in the environment. Dioxin emissions affect human health via direct exposure and through the food chain. High dioxin levels were found in dairy products which were produced near incinerators in France, the UK and the Netherlands, triggering agricultural losses and incinerator closures (ENDS 1998, Fierens *et al.* 2003, Vedura 2009, Szarka 2002, Greenpeace

France 2010, Greenpeace International 2010). Several studies of the health impacts of dioxin emissions from French incinerators have shown that they increase rates of non-Hodgkin's lymphoma (NHL) and soft-tissue sarcoma (Kogevinas *et al.* 1995, 1997). Floret *et al.* (2003) found NHL rates near the Besançon incinerator at twice the general population level. Viel *et al.* (2008) confirmed this finding for a larger region, even after controlling for density, urbanisation, socio-economic status, traffic and industrial pollution.

In addition to threats to agricultural production and public health, incinerators decrease local property values, as do other toxic and polluting sites (see Zuindeau and Letombe 2008 for a French case and Farber 1998 for a US summary). Polluting facilities can also generate social stigmas and psychological stress for residents (Gregory *et al.* 1995). Although these impacts have not been documented in France, efforts to site new incinerators typically generate strong opposition, suggesting an acute awareness of their impacts.

Networked national and international campaigns against incineration reveal growing public concerns about health risks and distrust in the management and regulation of incinerators. These campaigns emerged in the US in the 1970s (see Rootes 2009a, Rootes and Leonard 2009 for an overview) and are ongoing in Europe (e.g. Rootes 2009b on the United Kingdom, Leonard *et al.* 2009 on Ireland). Related movements in France are discussed in depth in McCauley (2009) and Szarka (2002). Some incinerator opposition campaigns have been successful in France. For example, an incinerator project in Alsace was defeated in 2004. Protests and legal battles took place in Marseilles in 2005, 2006 and 2008. Greenpeace France is leading these efforts (Greenpeace France 2010) and is working in collaboration with the Centre National d'Information Indépendente sur les Déchets and the Gaia network (Global Alliance for Incinerator Alternative). In 2007, a Group of Experts on the Risks of Incineration (GESDI) demanded a moratorium on the construction of new incinerators (Young 2007). While new incinerators are still planned, they are becoming increasingly difficult to site.

3. Methodology and analytical framework

Sensitivity analyses in the EJ literature have demonstrated empirically the impact of the choice of level of analysis on findings (e.g. Baden *et al.* 2007). When fine scales provide evidence of disproportionate impacts, large scales (e.g. the county or zip code in the US) can dilute this effect and make it less visible. In addition to selecting an appropriate scale, EJ analyses need to include relevant and appropriate control groups and statistical controls and to account for the spatiality of the phenomenon (see Laurian 2008b). Studies of the processes that yield environmental injustice also need to focus on community traits at the time of the siting.

The selection of a local level of analysis has several benefits. First, it avoids the 'dilution' effect of regional scales. Second, small areas best approximate risk exposures (McLeod *et al.* 2000, Bowen 2002, Mitchell and Dorling 2003). Third, headed by a mayor and council, the communes, or towns, used in this analysis are the smallest units of government in France. They cover the entire country and do not overlap. At the time of the 1999 census, there were 35,656 communes in metropolitan France. Hence, French towns are very small, with an average area of 14.9 km^2 and a median size of 10.7 km^2, exceptionally small for Europe. Therefore, they provide a fine level of analysis consistent with local decision-making jurisdictions.[8]

From the perspective of a regional planner or decision maker, the location of incinerators can be modelled as the change in unobserved latent net utility derived from siting an incinerator in town *i*. $y_i^* = U_{1i} - U_{0i}$ is the change in utility derived from locating an incinerator in town *i* compared to U_{0i} if it was sited elsewhere. The *benefits* to any town *i* derived under status 0 and status 1 are the same whether the incinerator is located locally or in a nearby town. However, a local incinerator lowers town *i*'s *costs* of transporting locally generated refuse to the incinerator, thereby increasing the net utility U_{1i} above U_{0i}. This difference in utilities gives rise to location decisions:

$$y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases}$$

The level of regional benefit derived from incinerators varies with the volume of waste generated, which is a function of size of the regional population and its economic output. If differences in other, non-transportation costs are negligible between alternative locations, the optimal pattern would site all incinerators in conurbations of population and employment that serve as median locations. Other costs are hypothesised to vary substantially across locations, however, and political costs understood by the regional decision maker(s) are the object of our interest. Contrary to transportation costs, political costs are higher under status 1 (town *i* receives the incinerator) than under status 0 (town *i* does not receive it) because people do not want to live near an incinerator. While concentrations of population and employment cause transportation costs to vary across potential incinerator locations, the concentrations of powerful (or vulnerable) people differentiate political costs across site alternatives.

Both monetary and political costs factor into the net utility for the model.

(1) Monetary costs include land prices within the town, the costs of transporting waste to the nearest incinerator, and the opportunity costs associated with locating an incinerator at the next best alternative site, presumably a neighbouring town.
(2) Political costs (our main interest in this analysis) also affect the perceived social utility gained from siting an incinerator in town *i*. Where the political costs are lower, we expect the latent change in net utility to be positive, increasing the probability of locating an incinerator in the town.

In the following sections, we develop a statistical model with spatial econometric controls that proxy for monetary costs including transportation and opportunity costs and the political environment that allows or prevents an incinerator from being sited within a particular town. The central hypothesis is that incinerators are located in communities with the least political power. We operationalise political costs as the proportion of unemployed people and the proportion of immigrants. Unemployment is the percentage of active residents (working or looking for work) who are unemployed. Immigration is measured both as the proportion of persons born abroad and as the proportion of foreigners. We do not include household income in the analysis because measures of town residents' median household income are not consistent across all censuses.

The log odds of receiving a new incinerator during the six years following a census are modelled as a linear function of these costs and benefits. We consider the six years following a census because intercensal periods in France are seven years or longer. The logit takes the form:

$$\log\left[\frac{\pi(y_{i,t} - y_{i,t-7} = 1)}{1 - \pi(y_{i,t} - y_{i,t-7} = 1)}\right] = \mathbf{X}_{i,t-6}\boldsymbol{\beta}_X + \varepsilon \tag{1}$$

where $\pi(y_{i,t} - y_{i,t-7} = 1)$ is the probability that town *i* received an incinerator within six years of a census, $y_{i,t}$ is a dichotomous variable valued 1 if town *i* has an incinerator in year *t* (six years after a census) and zero otherwise, $y_{i,t-7}$ indicates whether the town already had an incinerator the year before the census, $\mathbf{X}_{i,t-6}$ is a vector of census variables, $\boldsymbol{\beta}_X$ is the parameter vector to be estimated, and ε is an error term i.i.d. $N(0, \sigma^2)$. For year $t = 2005$, for example, the model estimates the conditional probability that a town received an incinerator after the end of 1998 ($t-7$) but before the end of 2005 (t), given values of the census variables reported for 1999 ($t-6$). Equation (1) is thus indexed as:

$$\log\left[\frac{\pi(y_{i,2005} - y_{i,1998} = 1)}{1 - \pi(y_{i,2005} - y_{i,1998} = 1)}\right] = \mathbf{X}_{i,1999}\boldsymbol{\beta}_X + \varepsilon$$

For the logistic regression, the dependent variable $y_{i,t} - y_{i,t-7}$ indicates whether town *i* received an incinerator in the six years following a census. We considered all 130 incinerators sited between 1965 and 2006. French censuses took place in 1968, 1975, 1982, 1990 and 1999. Since intercensal periods vary, we hold the period of observation constant by modelling the location of the 107 incinerators that opened within six years following a census.

The matrix $\mathbf{X}_{i,t-6}$ includes a column of ones for an intercept term and the variables described in Table 1. The odds of receiving an incinerator within six years of a census are modelled as a function of:

- local household and industrial waste stream generating demand for incineration, measured as the town's population, total employment and percentage of workers employed in manufacturing[9], and
- local political power, measured as the unemployment rate and percent immigrants.

Table 1 provides descriptive statistics for these variables.

In France, minority status cannot be directly analysed because the concepts of 'ethnicity' and 'minority' are not legally recognised, measured or collected on the grounds that race is not a biological reality.[10] The lack of data does not imply that residents' origin, skin tone or name does not shape their life chances. Nationality and place of birth, on the other hand, are commonly recorded. We thus focus on the proportion of immigrants, the vast majority coming from North and Sub-Saharan Africa. Recent immigration is captured by the population of foreigners and long-term immigration by the population of French citizens born abroad.

Given the uneven intercensal periods, we estimate Equation (1) separately for each of the five intercensal periods rather than temporally stacking or pooling the

Table 1. Descriptive statistics for independent variables.

	Mean (standard deviation)				
	$t-6=1968$	$t-6=1975$	$t-6=1982$	$t-6=1990$	$t-6=1999$
$y_{i,\ t-7}$	2.8×10^{-5} (527.5×10^{-5})	61.47×10^{-5} (2478.7×10^{-5})	102.9×10^{-5} (3206.8×10^{-5})	196.6×10^{-5} (4430.1×10^{-5})	290.3×10^{-5} (5380.1×10^{-5})
$Population_{i,\ t-6}$	1231.2 (6383.1)	1,362.7 (6895.1)	1,502.8 (8930.8)	1,527.2 (7388.7)	1,528.4 (6976.0)
$Employment_{i,\ t-6}$	490.0 (2595.5)	537.6 (2821.7)	594.8 (3494.1)	601.8 (2992.2)	574.2 (3678.8)
% $Unemployed_{i,\ t-6}$	1.2 (2.7)	2.8 (4.5)	7.4 (6.5)	9.4 (7.3)	10.3 (5.0)
% $Foreigners_{i,\ t-6}$	3.1 (5.6)	2.9 (5.4)	2.4 (4.5)	2.2 (3.9)	2.2 (3.0)
% $Born\ abroad_{i,\ t-6}$	5.1 (7.0)	5.1 (6.8)	4.8 (5.8)	4.7 (5.4)	4.7 (4.4)
% $Manufacturing_{i,\ t-6}$	17.7 (16.8)	29.9 (19.5)	28.4 (16.5)	27.2 (15.1)	10.4 (16.0)
Number of towns	35,937	35,788	35,943	36,107	35,826

five census years. We expect a positive relationship between the location of incinerators and variables measuring demand for incineration (population, employment and percentage of manufacturing). Based on the EJ hypothesis, we expect a positive relationship between the percentages of unemployed and immigrants and the location of incinerators.

3.1. Logit spatial lag of X model

Spatial lags of the variables are introduced to control for the likelihood that incinerators are located to satisfy regional demands of multiple towns and to control for opportunity costs – the benefits of an incinerator that accrue to neighbouring towns. The spatial model is:

$$\log\left[\frac{\pi\left(y_{i,t}-y_{i,t-7}=1\right)}{1-\pi\left(y_{i,t}-y_{i,t-7}=1\right)}\right]=\alpha_{t-7}(\mathbf{I}+\mathbf{W})y_{i,t-7}+\mathbf{W}\mathbf{X}_{i,t-6}\boldsymbol{\beta}_W+\mathbf{X}_{i,t-6}\boldsymbol{\beta}_X+\varepsilon \quad (2)$$

where $\mathbf{I}$ is an $n \times n$ identity matrix, $\mathbf{W}$ is an $n \times n$ row-stochastic spatial weights matrix indicating the 100 nearest neighbours of each town. α_{t-7} and $\boldsymbol{\beta}_W$ are a scalar and a parameter vector to be estimated. In matrix $\mathbf{W}$, $w_{i,j} = 0.01$ if column town j is among row town i's 100 nearest neighbours and $w_{i,j} = 0$ otherwise.[11]

Equation (2) is a logit version of the Spatial Lag of X Model, which deals strictly with spatial spillovers and differs substantively from a spatially autoregressive (SAR) probit model (LeSage and Pace 2009). The spatially lagged indicator of the presence of an incinerator one year before the census $(\mathbf{I}+\mathbf{W})y_{i,t-7}$ on the right-hand side of Equation (2) is predetermined and exogenous. An advantage of this formulation is that there is no need to spatially aggregate data for the 36,000 communes to larger spatial units to accommodate computing constraints. The small number of incinerators sited in each period relative to the large number of towns precludes the estimation of a SAR model. The events are rare (15 to 30 incinerators sited in each period) relative to the dimensions of the spatial weights matrix, which limits our ability to take advantage of sparse weights that would otherwise make the Gibbs sampling estimator practicable. Dense inverse-distance weights are impractical because we encounter a constraint of 16,384 columns for the dimensions of the weight matrix (well below the 36,000 by 36,000 required in our analysis).[12]

The 100 nearest neighbours matrix $\mathbf{W}$ is a compromise between dense and sparse weights. In theory, we should be able to use any sparse weighting scheme and obtain the same results. We favour asymmetric nearest neighbour weights for their theoretical implications and ease of use. Nearest neighbour weights are asymmetric, which means commune j might not be commune i's neighbour (one of the 100 nearest) even if commune i is commune j's neighbour. They assume (1) that proximity matters more than distance when towns compete for (or against) incinerators, and (2) that each town has a fixed number of 'competitor' towns regardless of its proximity to France's international borders. That is, each incinerator has a fixed capacity to serve a number of towns regardless of its location.[13] We sensitivity-test our results by using symmetric distance threshold weights and alternative specifications of the number of neighbours constituting a region.

The spatially weighted population and employment variables $\mathbf{WX}_{i,\ t\text{-}6}$ control for the opportunity costs associated with locating an incinerator in a neighbouring town.

When regional demand for waste incineration is large relative to local demand, the local net utility of hosting an incinerator would be low because costs are borne by town i while the benefits spill out to nearby towns.

If location decisions were strictly local and based on town i's expected benefits after opportunity costs, we would expect a negative relationship between its neighbours' demand for incineration (spatially weighted population, employment and percentage of manufacturing) and the location of incinerators in town i, holding the town's own demand constant. That is, a town would oppose a siting if most the benefits spillover to nearby towns. However, the possibility of regional decision making makes expectations ambiguous for spatially lagged demand variables. From a social cost minimisation standpoint, a large regional benefit (measured as the average population, employment and percentage of manufacturing of a town's neighbours) may be grounds enough to locate an incinerator in centrally located town i, regardless of the town's own benefit. If regional considerations dominate local ones, the estimated parameters on neighbouring demand variables would be expected to be positive.

Expectations are less ambiguous for the spatially weighted political cost variables. All else equal, having neighbours with less political power (higher rates of unemployment or immigration) is expected to reduce a town's probability of receiving an incinerator because the neighbour that lacks political power is more likely to receive the incinerator than town i. Therefore, we expect to find negative relationships between the odds of receiving an incinerator and neighbouring towns' unemployment rate, percentage of foreign born, and percentage born abroad.

The first term on the right-hand side of Equation (2) $\alpha_{t-7}(\mathbf{I}+\mathbf{W})y_{i,t-7}$ controls for transportation costs to the nearest pre-existing incinerator. If a town or one of its neighbours has an incinerator in $t-7$, its costs of transporting waste differ little between status 1 and status 0. The presence of incinerators in a region should lower the odds of receiving a new incinerator for towns in the region, *ceteris paribus*, due to the reduced opportunities for transportation cost reduction. We thus expect a negative estimate of α_{t-7}.

3.2. *Pooled periods: fixed effects specification*

The model in Equation (2) considers the benefits of eliminating waste, political, transportation and opportunity costs, but leaves out *land costs*, which may be an important factor in the siting decision. One would expect land prices to be inversely associated with the probability of receiving an incinerator and with political power. Since we lack time-series data for the price of land in each of the 36,000 communes, the findings for political costs' variables may overstate the magnitude of the true parameters and understate the variances of the coefficients. To minimise the missing variable bias, we pool the five time series and estimate a fixed effects specification:

$$\log\left[\frac{\pi\left(y_{i,t}-y_{i,t-7}=1\right)}{1-\pi\left(y_{i,t}-y_{i,t-7}=1\right)}\right] = \alpha_{t-7}(\mathbf{I}+\mathbf{W})y_{i,t-7}+\mathbf{W}\mathbf{X}_{i,t-6}\boldsymbol{\beta}_W+\mathbf{X}_{i,t-6}\boldsymbol{\beta}_X+F_i+F_t+\varepsilon \tag{3}$$

where F_i is a fixed effect for each commune i and F_t is a fixed effect for each time period t. Although no simple linear transformation exists to eliminate the incidental parameters in maximum likelihood estimation of the fixed effects logit model, the conditional maximum likelihood estimator is a consistent estimator of parameter vector β under suitable regularity conditions (Chamberlain 1980, Hsiao 2003). We estimate the parameters in Equation (3) by maximizing the conditional logit form of the log-likelihood function for the five periods (1999 is the reference period).

This fixed effects logit specification represents a potential improvement for correcting the missing variable bias if the missing land prices are time-invariant. Since they probably vary over time with demand for land, the estimators are likely to remain biased, overstate the influence of political power as a determinant of incinerator locations, and increase the probability of a type I error. On the other hand, in France land values are known to be highly correlated with towns' population size. It is likely that type I error risk is negligible if the impact of land values on siting decisions is in effect captured by the population size variable.

4. Findings

Overall, few incinerators were constructed in towns with populations over 100,000 at the time the incinerator opened, suggesting that planners steer away from locating incinerators *in* large population centres but rather select smaller communes *near* population centres (presumably where land is cheap and political opposition weak). Table 2 depicts the population distributions of towns with incinerators at the time of their siting. Approximately one-third of all incinerators opened in towns with a population between 10,000 and 50,000. Another one-third were sited in towns with populations under 5000. These facilities probably serve regional markets – so that at least in these cases, siting decisions can be expected to be regional rather than local.

Table 3 illustrates differences, at the time of the siting, between the towns that received incinerators and their nearest 25, 50, 100 and 200 neighbours. The average, median and maximum *ratio* of town-to-neighbours unemployment rate, proportion of foreigners and those born abroad for each regional 'scale' reveal that towns that received incinerators had on average 1.3 to 1.6 times higher unemployment rates than their neighbours. This average ratio is fairly constant over all time periods and whether we consider the closest 25 to 200 neighbours. The proportion of immigrants (foreigners and those born abroad) was 1.7 to 3.7 times higher in towns that received incinerators than the average of their neighbours. For example, towns that received incinerators during the periods 1982–89 and 1990–98 had proportions of foreigners 2.7 to 3.7 times higher than their closest neighbours. Towns that received incinerators between 1968 and 1974 had proportions of persons born abroad on average 2.5 to 2.9 times the proportion of those born abroad of their 25, 50 and 100 closest neighbours.

Towns that received incinerators had higher proportions of immigrants than their neighbours at the time of the siting. These ratios – indicating bias in siting decisions – are greater than one by a consistent order of magnitude in every time period. While the ratios vary somewhat between time periods, they display no increasing or decreasing trends between 1968 and 2003. Overall, towns were more similar to their closest neighbours than to their wider region. Sharp increases in these gaps appear between the 100 neighbour and the 200 neighbour comparison groups, especially for the periods 1968–74 and 1975–81. The decision to select towns' 100 closest neighbours for the analysis therefore allows the largest comparison group while avoiding the distortion that 200 neighbour regions would generate.

Table 2. Population distribution of towns with incinerators at time of siting.

Year of census	1968	1975	1982	1990	1999	Total
Intercensal period (years)	1969–75 (7)	1976–82 (7)	1983–90 (8)	1991–99 (9)	2000–06 (7)	
Number of towns receiving an incinerators in the 6-year period following a census*	21	15	30	20	21	107
Population size (%) at the time of the siting						
<5000	7 (33.3%)	6 (31.6%)	9 (23.7%)	13 (40.6%)	6 (33.3%)	41 (32.0%)
5000–10,000	2 (9.5%)	1 (5.3%)	2 (5.3%)	2 (6.3%)	1 (5.6%)	8 (6.25%)
10,000–50,000	3 (14.3%)	7 (36.8%)	15 (39.5%)	11 (34.4%)	6 (33.3%)	42 (32.8%)
50,000–100,000	2 (9.5%)	2 (10.5%)	6 (15.8%)	2 (6.3%)	2 (11.1%)	14 (10.9%)
100,000–150,000	4 (19.0%)	1 (5.3%)	1 (2.6%)	2 (6.3%)	3 (16.7%)	11 (8.6%)
>150,000	3 (14.3%)	2 (10.5%)	5 (13.2%)	2 (6.3%)	0 (0.0%)	12 (9.4%)

Note: *128 incinerators were sited between 1968 and 2006, 107 of these were sited within six years of a census.

Table 3. Mean, median and maximum ratios of unemployment rates, proportion of foreigners and proportions of persons born abroad for towns that received incinerators vs. their nearest 25, 50, 100 and 200 neighbours (at the time of the siting),* i.e. towns that received incinerators had on average 1.3 to 1.6 times higher unemployment rates than their neighbours.

Number of neighbours	1968–74			1975–81			1982–89			1990–98			1999–03		
	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max
Unemployment rate															
25	1.4	1.5	2.4	1.3	1.2	2.8	1.5	1.5	2.4	1.4	1.4	2.7	1.4	1.5	2.4
50	1.4	1.5	2.7	1.3	1.1	3.3	1.4	1.4	2.7	1.3	1.3	2.9	1.5	1.5	2.8
100	1.5	1.4	3.2	1.3	1.3	2.4	1.4	1.4	2.4	1.3	1.3	2.5	1.5	1.4	3.0
200	1.6	1.7	2.8	1.4	1.3	2.7	1.4	1.4	2.2	1.3	1.4	2.4	1.4	1.4	3.1

Number of neighbours	1968–74			1975–81			1982–89			1990–98			1999–03		
	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max
Proportion of foreigners															
25	2.0	1.1	15.5	1.7	1.7	4.0	3.7	3.1	13.1	2.7	2.3	8.9	2.1	2.1	5.4
50	2.4	1.2	19.5	2.2	1.8	5.9	3.6	3.4	11.2	2.8	2.1	8.0	2.3	2.4	5.9
100	2.7	1.3	22.0	2.3	1.8	7.0	3.5	2.6	12.2	2.7	2.1	10.1	2.4	2.4	7.0
200	3.7	1.6	36.6	2.6	1.8	7.0	3.6	3.0	9.3	2.8	2.0	9.0	2.3	2.1	5.6

Number of neighbours	1968–74			1975–81			1982–89			1990–98			1999–03		
	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max
Proportion of persons born abroad															
25	2.4	1.3	17.8	1.5	1.5	3.9	2.1	2.1	4.6	1.7	1.7	3.9	1.6	1.6	3.2
50	2.5	1.3	14.9	1.9	1.4	5.7	2.1	2.0	5.2	1.8	1.8	4.4	1.7	1.7	3.8
100	2.9	1.4	17.1	2.0	1.5	5.9	2.2	2.4	5.2	1.8	1.7	4.2	1.9	1.7	5.1
200	3.7	1.7	24.6	2.3	1.5	5.9	2.3	2.3	5.7	1.9	1.7	4.6	1.9	1.6	6.0

Note: *Minimum values were all at, or close to, zero.

Table 4 reports the results of the spatial logistic regression modelled in Equation (2). For all five census periods, including the spatially lagged X variables and the information about incinerator locations prior to the census, increased the maximised log likelihood, the likelihood ratio and pseudo R^2, all suggesting improvement in model fit over the non-spatial model (Equation 1 results are provided in the Appendix). The Akaike Information Criterion suggests that the improvement in fit is worth the trade-off in additional parameters to be estimated for years 1982 and 1990. The Hosmer-Lemeshow tests (Hosmer and Lemeshow 2000) for fit across deciles of the predicted probabilities suggest a satisfactory fit in the models for each of the five census periods, despite the continuous variables included in the models.

With the spatially lagged variables, the models for census years 1968, 1975, 1990 and 1999 yield significant findings. All the variables' coefficients in the models are estimated with the expected signs. A greater proportion of foreigners or proportion of persons born abroad in a town is associated with higher odds that the town received an incinerator. This effect is significant in 1968 (for the proportion of foreigners), in 1975 and 1990 (for both the proportion of foreigners and those born abroad) and in 1999 (for the proportion of persons born abroad). All else equal, a 1% increase in foreign population raised the odds of receiving an incinerator in the town by about 9% in 1968, 7% in 1975, and 14% in 1990. Similarly, a 1% higher rate of persons born abroad increased a town's odds of receiving an incinerator by 9% in 1975, 13% in 1990 and 11% in 1999. Although these biases in siting decisions vary in strength between time periods, they are significant and consistently disfavour towns with concentrations of foreigners and people born abroad.

As expected, the higher the proportion of immigrants in nearby towns, the lower the odds that a town i receives an incinerator. This effect is significant and large for the proportion of foreigners in 1968 and 1990 and for the proportion of persons born abroad in 1975 and 1990. For each additional percentage of foreigners in nearby towns, town i had lower odds of receiving an incinerator by 22% in 1968 and 24% in 1990. For each 1% increase in persons born abroad in nearby towns, town i's odds of receiving an incinerator decreased by 13% in 1975 and 18% in 1990.

Other significant estimated coefficients in the model for 1999 include the log of employment, the spatially weighted logs of employment and population, and the number of pre-existing incinerators among the 100 nearest neighbours in the region. After controlling for a town's population and the amount of overall economic activity in its region, the coefficient on employment greater than one means that a commune with twice the employment has more than double the odds of hosting an incinerator. In 1999, incinerators were sited in regional employment centres among communes of comparable population size, although no incinerators were sited in communes with a population greater than 100,000. On the other hand, a doubling of regional population among a commune's 100 nearest neighbours is associated with a four-fold increase in the odds the commune received an incinerator. Consistent with the partiality towards employment centres, a doubling of average employment among neighbours substantially reduced the odds that a town would receive an incinerator. The very large negative coefficient on $(\mathbf{I} + \mathbf{W})y_{i,t-7}$ means that the odds of receiving an incinerator drop very near to zero when one of the commune's 100 nearest neighbours already has an incinerator. That is, incinerators are spatially dispersed. In the 1975 model a town in a region with a large manufacturing base had higher odds that it received an incinerator.

Table 4. Spatial logistic regression results for Equation (2).

Variable	Coefficient (standard error)									
	$t-6=1968$		$t-6=1975$		$t-6=1982$		$t-6=1990$		$t-6=1999$	
Intercept	−23.7*** (4.62)	−23.4*** (4.52)	−21.6*** (4.53)	−21.7*** (4.52)	−8.7** (3.87)	−8.7** (3.94)	−14.5*** (5.18)	−14.1** (5.12)	−21.6*** (3.99)	−21.4*** (4.02)
$(\mathbf{I}+\mathbf{W})y_{i,\ t-7}$	−106.71 (128.71)	−93.78 (127)	−4.50 (9.66)	−4.66 (10.40)	−8.93 (24.53)	−16.60 (40.79)	−6.02 (8.03)	−6.39 (9.52)	−134.5** (58.11)	−131.1** (57.59)
Log(*Population*)$_{i,\ t\text{-}6}$	1.63 (2.50)	1.44 (2.62)	1.35 (2.42)	1.36 (2.33)	0.34 (2.70)	0.54 (2.67)	−0.31 (2.88)	0.39 (2.63)	−0.30 (0.46)	−0.36 (0.46)
WLog(*Population*)$_{i,\ t\text{-}6}$	3.35 (4.26)	3.49 (4.28)	2.67 (4.33)	2.67 (4.28)	−4.06 (4.53)	−3.78 (4.52)	2.09 (5.28)	1.43 (5.33)	3.31** (1.47)	3.29** (1.44)
Log(*Employment*)$_{i,\ t\text{-}6}$	−0.12 (2.46)	0.04 (2.57)	−0.21 (2.35)	−0.24 (2.26)	1.01 (2.67)	0.82 (2.64)	1.55 (2.84)	0.86 (2.61)	1.24*** (0.37)	1.27*** (0.38)
WLog(*Employment*)$_{i,\ t\text{-}6}$	−3.04 (4.07)	−3.20 (4.08)	−2.61 (4.12)	−2.57 (4.07)	3.72 (4.43)	3.33 (4.41)	−2.03 (5.16)	−1.48 (5.20)	−2.65** (1.20)	−2.64** (1.18)
% *Manufacturing*$_{i,\ t-6}$	−0.04 (0.02)	−0.03 (0.03)	−0.03 (0.02)	−0.03 (0.02)	−0.03 (0.02)	−0.03 (0.02)	−0.02 (0.03)	−0.02 (0.03)	−0.02 (0.02)	−0.02 (0.02)
W% *Manufacturing*$_{i,\ t-6}$	0.00 (0.04)	0.00 (0.04)	0.07* (0.04)	0.07* (0.04)	0.02 (0.03)	0.03 (0.03)	−0.04 (0.048)	−0.04 (0.05)	0.02 (0.07)	0.02 (0.07)
% *Unemployed*$_{i,\ t-6}$	−0.16 (0.27)	−0.11 (0.27)	−0.01 (0.16)	−0.02 (0.16)	0.06 (0.08)	0.06 (0.08)	−0.04 (0.09)	−0.03 (0.09)	0.003 (0.08)	−0.02 (0.07)
W% *Unemployed*$_{i,\ t-6}$	0.64 (0.54)	0.66 (0.55)	0.35 (0.39)	0.37 (0.41)	−0.33* (0.20)	−0.36* (0.20)	−0.12 (0.184)	−0.13 (0.19)	0.003 (0.13)	0.03 (0.12)
% *Foreigners*$_{i,\ t-6}$	**0.09* (0.04)**		**0.07* (0.04)**		**0.02 (0.05)**		**0.13*** (0.05)**		**0.05 (0.08)**	
W% *Foreigners*$_{i,\ t-6}$	**−0.25** (0.10)**		**−0.13 (0.12)**		**−0.13 (0.12)**		**−0.28* (0.143)**		**0.02 (0.17)**	
% *Born abroad*$_{i,\ t-6}$		**0.03 (0.07)**		**0.09** (0.04)**		**0.01 (0.06)**		**0.12*** (0.04)**		**0.10** (0.05)**
W% *Born abroad*$_{i,\ t-6}$		**−0.13 (0.09)**		**−0.14* (0.09)**		**−0.03 (0.09)**		**−0.20** (0.09)**		**−0.08 (0.10)**
Log likelihood	−100.3	−101.3	−93.74	−93.3	−150.0	−150.5	−119.0	−119.09	−118.7	−117.57
Likelihood ratio (for all $\Pr > \chi^2 < 0.001$)	154.1	152.0	75.83	76.6	185.2	184.3	102.0	101.8	117.1	119.4
Pseudo R^2	0.44	0.43	0.29	0.29	0.38	0.38	0.30	0.30	0.33	0.34
Hosmer-Lemeshow Fit ($\Pr > \chi^2$)	3.0 (0.93)	3.4 (0.91)	4.9 (0.77)	2.30 (0.97)	6.82 (0.56)	6.62 (0.58)	14.13 (0.08)	9.33 (0.32)	14.1 (0.08)	7.1 (0.52)
Akaike info. criterion	224.6	356.7	211.5	210.671	324.0	325.0	261.9	262.2	355.5	259.1
Number of obs.	35,937 (21 $Y=1$)		35,788 (15 $Y=1$)		35943 (30 $Y=1$)		36,107 (20 $Y=1$)		35,826 (21 $Y=1$)	

Note: $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Among the time periods we examined, we found the weakest evidence of environmental injustice for incinerators sited after the 1982 census, when towns that neighbour communes with high unemployment rates were less likely to open an incinerator. No other political cost variable is statistically significant for that period although at least one immigrant variable is significant for all other periods we studied. However, the coefficients on the immigration variables for the 1982 models have the expected signs and are not trivial in magnitude. We considered whether multi-collinearity inflated standard errors and prevented the rejection of null hypotheses for the immigration variables. We examined the principal components of the correlation matrix to assess its severity. The collinearity condition number exceeds 30 for 1982 and 1990. A condition index greater than 30 may indicate a problem with multi-collinearity. For 1999, the year with the most interesting results, the condition number is smallest and the precision allows us to reject the null hypothesis of no effect for more variables than for any other time period. For 1982 and 1990, variance inflation factors indicate that inclusion of both spatially weighted logs of population and employment is the largest source of inefficiency, followed by the inclusion of both log of employment and log of population. However, parsimonious models excluding one or more of the multicollinear measures (not presented here) reveal similar findings overall.[14]

The fixed effects model in Equation (3) is designed to control for unobserved heterogeneity among towns that might otherwise explain the siting of an incinerator. We use conditional maximum likelihood to exploit the within-town variation over time and control for these unobserved differences. Table 5 reports these results.

The pooled model is consistent with the findings reported in Table 4. The odds of receiving an incinerator are elastic with respect to a town's own demand for waste incineration, measured by its population. A doubling of population more than

Table 5. Pooled spatial logistic regressions results for Equation (3).

Variable	Coefficient (standard error)
$\mathbf{W}y_{i,\ t-7}$	−8.283 (31.366)
Log(*Population*)$_{i,\ t\text{-}6}$	2.679** (0.947)
WLog(*Population*)$_{i,\ t\text{-}6}$	2.506 (1.997)
Log(*Employment*)$_{i,\ t\text{-}6}$	−0.775 (0.606)
WLog(*Employment*)$_{i,\ t\text{-}6}$	−4.860** (1.626)
% *Unemployed*$_{i,\ t-6}$	−0.003 (0.061)
W% *Unemployed*$_{i,\ t-6}$	−0.112 (0.114)
% *Manufacturing*$_{i,\ t-6}$	0.004 (0.022)
W% *Manufacturing*$_{i,\ t-6}$	0.020 (0.036)
% *Foreign born*$_{i,\ t-6}$	0.256** (0.090)
W% *Foreign born*$_{i,\ t-6}$	−0.215 (0.261)
% *Born abroad*$_{i,\ t-6}$	−0.170 (0.094)
W% *Born abroad*$_{i,\ t-6}$	0.048 (0.256)
Fixed effect for each commune	Yes
Time-series dummies	Yes
Log likelihood	−155.433
Likelihood ratio [Pr > $\chi^2(k)$]	33.552 (0.009)
Pseudo R^2	0.097
Akaike information criterion	344.867
Number of obs.	179,601 (107 $Y=1$)

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

triples the odds of receiving an incinerator. Conversely, when neighbouring towns would enjoy more of the benefits of an incinerator, the odds decline dramatically. The estimated coefficient for spatially lagged employment is significantly negative and elastic. After controlling for these spatial externalities, access to existing incinerators and direct benefits to the town, we find a positive effect for one political cost variable. For each additional 1% foreign born in a town, the odds increase by 29% that the town received an incinerator. These results are robust to the specification of alternative spatial weights. When we substitute symmetric distance threshold weights for our asymmetric 100 nearest neighbour weights in Equations (2) and (3), we estimate nearly identical results.[15] This evidence supports the EJ hypothesis that towns with more immigrants are disproportionately likely to receive incinerators.

5. Conclusions

This analysis of environmental justice in France, the first spatial econometric European study to account for vulnerable populations at the time of siting, shows that environmental inequities observed in North America hold true in Europe. We explore the cause of these inequities by linking the siting of new incinerators to population characteristics at the time of each siting. The analysis supports the hypotheses that towns with higher proportions of immigrants (foreigners and persons born abroad) are more likely to receive incinerators, *ceteris paribus*. From the pooled model, we find that for each additional 1% of a town's population that is foreign born, the odds that the town received an incinerator increases by 29%, holding all else constant.

Towns with high proportions of immigrants today are more likely to host incinerators (Laurian 2008a), which amounts to distributional inequity. This analysis reveals procedural inequities: at the time of the sitings, towns with more immigrants were more likely to receive an incinerator and towns whose neighbours had more immigrants were less likely to receive one. Inequities are thus due, at least in part, to biased siting decisions that target towns with high proportions of immigrants. Since unemployment rates do not significantly affect siting decisions overall, it is unlikely that towns that received incinerators were seeking jobs and revenue-generating facilities.

Additional case studies on the socio-political factors of incinerator location or successful opposition (e.g. McCauley 2009) are needed to yield lessons that can be generalized about the locus and dynamics of decision-making powers. These studies should consider the relationships between localities, departments and regions, local mayors and elected officials, non-government organisations and political parties, as well as their respective motivations, political capital and resource mobilisation strategies.

5.1. Methodological advances

This study presents a significant methodological advance in the field of environmental justice analysis. Multiple cross-sections for each inter-census period are necessary, given the spatial and historical nature of EJ-related phenomena. Our key contribution is to apply a spatially weighted logistic regression model with controls for unobserved heterogeneity to the question of environmental injustice when the number of events modelled is very small relative to the number of spatial units. The modelling of events (here 107 incinerators sited among 36,000 towns over a 40-year period) is typically dealt with by random sampling into two strata – towns that received incinerators and those that did not – or matching controls to cases. However, such approaches omit important spatial information that factors into site-selection processes.

We know of no previous study that estimates conditional probabilities in an EJ framework that dynamically accounts for changing regional conditions (that is, spatial spillovers), particularly the siting of an unwanted land use in a neighbouring community that may make the particular community irrelevant as an alternative for future regional site selection purposes. Spatially dispersed patterns of unwanted land use distribution suggest that statistical models lacking similar controls for irrelevant alternatives produce biased probability estimates. Our framework controls these factors. The spatially lagged variables introduce controls for the benefits of siting an incinerator that would spill out to neighbouring towns and the opportunity costs associated with the next best alternative location. The spatially weighted locations of pre-existing incinerators control for the fact that the costs of shipping waste are lower when an incinerator is already located nearby.[16]

The analysis considers all census periods since 1968. However, it does not track socio-economic or demographic changes over time for communes that received incinerators. It is possible that they become even more disenfranchised (because the incinerator is undesirable and may reduce property values, thus increasing the proportion of poor and immigrants to the town). This paper was designed to identify biases in siting rather than to investigate these potential impacts over time. Future studies on the evolution of towns with incinerators should contrast them to their neighbours and account for exogenous local socio-economic changes over time.

5.2. *Implications*

Finally, finding environmental inequalities in France raises important public policy questions. While uniform pollution reduction policies may not redress inequalities, policies that mitigate the impacts of unjustly located facilities can mitigate risks in the most affected communities and reduce inequalities (Todd and Zografos 2005). However, emission standards were not fully enforced until 2008, raising questions about the implementation of European policies in France.

For future sitings, procedural justice requires democratic decision making at local and regional levels (Lake 1996, Dobson 1998, Hunold and Young 1998, Schlosberg 1999, 2003, Agyeman and Evans 2004, Watson and Bulkeley 2005). The 1998 EU Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (UNECE 1998) was the first step in this direction. Participatory democracy has the potential to correct inequalities if all stakeholders are equally able to shape decisions. Yet, in practice, better-off populations benefit disproportionately from access to information, political and judicial systems. Furthermore, the legal rights of advocacy groups are limited in France in the absence of class action lawsuits.[17] Despite this limitation and the absence of a formal EJ movement in France, the anti-incineration campaign led by Greenpeace France and the 2007 formal condemnation of incineration by French scientists suggests that collective action is emerging.

France does not yet recognise environmental injustice in its laws and procedures, and EJ analyses are not required in environmental impact assessments. As this and other studies contribute to an increasing body of evidence on distributive and procedural environmental injustice, we hope that France will adopt policies to redress inequities. We expect that the French resistance to acknowledging racial inequities, for which immigration is a proxy here, could take French policies on paths not followed by other countries. In France as elsewhere, equity issues can only be addressed if politicians become aware of the biases demonstrated here and committed to tackling them, and if national and regional policies on incinerator location (or suppression) follows suit. It is unclear whether the political will exists at this time to address this decade-long problem.

Notes

1. While Laurian (2008a) considered the current spatial distribution of incinerators and many other polluting sites, it did not explore the characteristics of local populations *at the time of the siting*.
2. The US EPA defines Environmental Justice as ‘the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies’. Available from: http://www.epa.gov/oecaerth/environmental justice/
3. In the US, Lavelle and Coyle (1992) showed that steeper sanctions were imposed on polluters in white and affluent communities (see also Mennis 2005 on inequities in air quality enforcement in New Jersey). In The Netherlands, Coenen and Halfacre (2003) found that cleanups are sometimes more expedient in better-off communities.
4. In 1992, France adopted the goal of closing all landfills except those that accept ‘ultimate waste,’ i.e. by-products of incineration, medical and hazardous waste. Many landfills were closed in the 1990s and approximately 350 remain in operation.
5. Dioxin includes different types of compounds. The most toxic, 2,3,7,8-tetrachlorodi-benzo-p-dioxin (2,3,7,3 -TCDD) is recognised as a carcinogen by the US EPA and the ATSDR (Floret *et al.* 2003).
6. Ministerial Decree of 20 September 2002. The 2000 European Directive also imposes standards for NO_x, SO_2, Particulate Matter and heavy metals.
7. Approximately 80 French incinerators have closed since the 1970s, some in the 1990s but most after the 2002 regulations took effect (Greenpeace France 2010).
8. Incinerator approval is finalised by the prefect (heads of departments) and should be consistent with departmental and regional waste management plans. Yet, local mayors have significant roles to play in siting processes and opposition (e.g. see the cases studies in McCauley 2009). In-depth analyses of the locus of political power in incinerator siting, which is not the object of this paper, will require additional qualitative case studies.
9. This includes extraction, chemical and heavy and light manufacturing industries (using 2-digit occupation codes for each census).
10. This outlook stems from the use of ethnic minority registration during the Second World War and from policies that expect immigrants to integrate rather than maintain their cultural identities.
11. A town’s 100 nearest neighbours are identified from all bilateral Euclidean distances between pairs of town centroids.
12. We encountered the 16,384 column limit for dense spatial weights in Matlab version 7.9.0 for 64-bit on a 64-bit personal computer with eight parallel processors, each at 2.66 GHz and 4 GB RAM with paging to hard disk.
13. Symmetric sparse weights, on the other hand, assume that distance matters more than proximity for inter-town competition and that incinerators near the border serve fewer towns than in the interior.
14. When employment is excluded the effects of population size on the odds of receiving an incinerator become significantly positive for all years.

15. For the model with distance-threshold weights, the effect of a 1% higher concentration of those who are foreign born is estimated to be 27% higher odds. These results are available from the authors upon request. We selected a distance of 34 km to approximate 100 nearest neighbours for an interior commune with an incinerator arbitrarily chosen (Nevers). 34 km is the radius required to identify 115 neighbours of Nevers, equivalent to five orders of contiguity.
16. Although the Bayesian spatial probit model is gaining wide popularity for purposes similar to ours, it is impractical in cases when the events are very rare and the number of spatial cross-sections is very large. For these circumstances, we present an alternative to the spatial probit model.
17. Proposed in 2006 and withheld in 2007, the notion of class action 'recours collectif ' was suppressed by the 2008 Law on the Modernisation of the Economy.

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Appendix

Non-spatial model

The model in Equation (1) is estimated using the natural logs of population and employment because the logarithmic form of these variables improves all indicators of fit for the five Census years. Nonetheless, the estimators for the demand and political cost variables remain inefficient. The log of employment is significant only in 1999, when the estimated coefficient is positive and elastic, consistent with expectations. Doubling the size of a town's economic base more than doubles the odds of receiving an incinerator – it increases the odds by 121%.

Two political cost variables, percentage of foreigners and percentage born abroad, are significant only in 1968. Consistent with the EJ hypothesis, the estimated coefficients for foreign born implies that a 1% increase in a town's share of population who are foreigners is associated with a 17% increase in the odds of receiving an incinerator. The estimated coefficient for the percentage of those born abroad in the same year, however, is significantly negative, which is inconsistent with the EJ hypothesis. It is the only instance in our models where an estimated coefficient differs in sign from expectations. This negative parameter estimate is indicative of the strong positive association between the percentage of foreigners and percentage born abroad. Zero-order correlation coefficients for these variables range from 0.76 in 1990, 0.83 in 1968 and to 0.85 in 1999.

Table A1. Non-spatial logistic regression results for logged continuous variable form of Equation (1).

Variable	Coefficient (standard error)				
	$t-6=1968$	$t-6=1975$	$t-6=1982$	$t-6=1990$	$t-6=1999$
Intercept	−20.6012*** (2.4270)	−18.4727*** (2.6499)	−14.8857*** (2.1362)	−14.8258*** (2.5377)	−13.0868*** (1.3931)
Log($Population$)$_{i,\ t\text{-}6}$	3.3340 (1.7488)	3.1796 (1.7374)	−0.5037 (2.1851)	1.2654 (2.3235)	−0.3927 (0.4345)
Log($Employment$)$_{i,\ t\text{-}6}$	−1.7291 (1.6950)	−2.0305 (1.6457)	1.7758 (2.1567)	−0.2097 (2.2644)	1.2059** (0.3685)
% $Unemployed_{i,\ t-6}$	0.0659 (0.1366)	−0.0364 (0.1421)	0.0165 (0.0840)	−0.0159 (0.0742)	0.0584 (0.0460)
% $Manufacturing_{i,\ t-6}$	−0.0399 (0.0211)	−0.00160 (0.0195)	−0.00114 (0.0193)	−0.0215 (0.0248)	−0.00222 (0.0161)
% $Foreign\ born_{i,\ t-6}$	0.1720* (0.0771)	0.0407 (0.0691)	0.0648 (0.0723)	0.1119 (0.0767)	−0.0921 (0.0879)
% $Born\ abroad_{i,\ t-6}$	−0.1392* (0.0630)	0.00887 (0.0590)	−0.0950 (0.0631)	−0.0683 (0.0709)	0.0947 (0.0652)
Log likelihood	−101.7405	−97.2795	−163.84	−127.121	−129.936
Likelihood ratio \[Pr > χ^2 (6)]	151.1971 (<0.001)	68.7542 (<0.001)	157.6047 (<0.001)	85.6876 (<0.001)	94.6754 (<0.001)
Pseudo R^2	0.4275	0.2618	0.3262	0.2530	0.2680
Hosmer-Lemeshow fit statistic [Pr > χ^2 (8)]	16.4825 (0.0360)	7.1566 (0.5198)	6.0363 (0.6432)	6.8232 (0.5558)	6.8460 (0.5533)
Akaike information criterion	217.481	208.559	341.680	268.242	273.872
Number of obs.	35,937 (21 $Y=1$)	35,788 (15 $Y=1$)	35,943 (30 $Y=1$)	36,107 (20 $Y=1$)	35,826 (21 $Y=1$)

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.