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Transforming incinerators into community amenities? The Seoul experience

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This article explores the possibility that pairing desirable community amenities with polluting, industrial, or otherwise unwanted sites, such as waste incinerators, may have the potential to mitigate, or even compensate for, some of their negative local impacts. The environmental justice literature shows that polluting sites tend to disproportionately affect low income and disenfranchised communities. Could this be reversed or mitigated by linking positive amenities to polluting sites? The South Korean experiment of building community amenities (recreation centers, pools, gyms, etc.) at waste incinerators may provide answers to this intriguing question. Using the Difference-in-Differences design we found that while incinerators without amenities have substantial negative impacts on local land and real estate markets, we did not observe any such impact in areas with incinerators that have amenity features. Thus, the amenity features of the incinerators (along with enhanced regulatory emissions standards) are mitigating the negative economic impacts of incinerators.

Keywords: incinerators; environmental justice; amenities; impact mitigation; property values

1. Introduction: incinerators, their benefits and negative impacts

Many countries rely on waste incineration as a primary mode to process municipal solid waste. This choice can stem from a shortage of land for landfills, e.g., Japan, South Korea, Luxembourg, and Netherlands. It can also stem from policy preferences. In the European Union (EU), landfilling has, overall, not been considered a good waste disposal alternative since the 1999 Landfill Directive (EU Council 1999). Most countries that incinerate also capitalize on energy and heat recovery from Waste-to-Energy incinerators, typically in association with district heating systems e.g., France, Germany, Denmark, Sweden, Belgium, Japan, South Korea (Persson and Münster 2016, Ryu and Shin 2013). Countries with some of the heaviest reliance on incineration include France (MDD 2010), Scandinavian nations (Denmark, Norway, and Sweden) and Japan, which incinerates about 80% of its waste post recycling (Sugahara *et al.* 2015, Hunsicker, Crockett, and Labode 1996).

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Waste-to-Energy incinerators provide several benefits: they dramatically reduce the need for landfills and landfill space; they eliminate the issue of landfill leachate (although they produce airborne emissions); and they provide an ongoing source of energy that can be used for heating and cooling nearby buildings. Waste incineration is often considered a source of renewable energy, although it also diminishes incentives to reduce waste streams by recycling, both at the household and government levels

Furthermore, and perhaps more importantly, despite significant progress in emission reductions technologies and regulations in the West, as well as in Asia, incinerators still generate toxic emissions. They negatively affect public health, and indirectly generate social stigmas that can reduce nearby property values. These health, economic and social impacts are not borne equitably by the whole population but can, instead, create or increase injustices in the distribution of environmental impacts. This section briefly reviews the literature on the impacts of incinerators, with a special emphasis on the South Korean situation.

Waste incinerators have well-known detrimental impacts on public health (Allsopp, Costner, and Johnson 2001, Fierens *et al.* 2003). They release dioxin compounds,¹ heavy metals, polycyclic aromatic hydrocarbons and particulate matter. Of particular concern, incinerators are a leading source of dioxin emissions in Western Europe and North America (US EPA 2006). Although increasingly stringent air quality regulations have lowered emissions (e.g., the 2000 EU directive in Europe², the 2000 Amendment of South Korean Air Quality Management Act³), dioxins and heavy metals remain in the environment long after they are emitted. Dioxins affect human health via direct exposure and through the food chain. For instance, high dioxin levels were found in dairy products near incinerators in France, UK, the Netherlands and Italy (Greenpeace France 2010, Vedula 2009, Szarka 2002, Candela *et al.* 2015). French studies have found that dioxin emissions from incinerators increase rates of non-Hodgkin's lymphoma (NHL) and soft-tissue sarcoma (Kogevinas *et al.* 1997). Floret *et al.* (2003) and Viel *et al.* (2008) found the NHL rates near an incinerator to be twice as high as in the general population, even after controlling for density, urbanization, socio-economic status, traffic and industrial pollution. Shim, Rhee, and Lee (2005) found high concentrations of heavy metals (lead, cadmium) in the bottom and in fly ashes in Japan and Korea, with higher levels of leaching in Korea. Furthermore, at least in the years 2000-2010, GHGs emissions from incinerators in South Korea were increasing by 10% per annum (Park, Choi, and Park 2011). On the other hand, the Korean Institute for Environmental Research found minimal concentrations of heavy metals and dioxins in residents' blood samples around four incinerators in Seoul (2013). However, the authors warned that long-term monitoring of residents' health and more robust analytical methods are required to fully assess the effects of incinerators on residents' health (Institute for Environmental Research 2013).

As a result of actual emissions and health risks, through the truck traffic they generate, as well as *perceived* emissions and health risks, incinerators reduce demand for housing in surrounding areas and negatively impact property values (e.g., Zuindeau and Letombe 2008 in France, Farber 1998 in the US). The combination of the negative health and economic impacts also generates stress and social stigmas, adding to the burden put on residents (Gregory and Flynn 1996, Dory *et al.* 2017).

These burdens are typically not distributed randomly or fairly across the population, but tend to disproportionately impact low income populations, minorities and

disenfranchised groups. The resultant environmental injustice can stem from (1) targeting disenfranchised communities or neighborhoods when siting new incinerators, (2) the lesser ability of disenfranchised communities to successfully oppose incinerator projects, (3) the disproportionate ability of the wealthiest to move away from incinerators, and/or (4) the extent to which low income populations disproportionately move into the vicinity of incinerators in search of lower property values. Regardless of the process, or combination of processes involved, the result is environmental injustice in the impacts of incinerators. This has been demonstrated in the case of incinerators and waste processing plants (e.g., US GAO 1983, UCCRJ 1987 in the US, Laurian 2008a, Laurian and Funderburg 2014 and Benmarhnia, Schwarz, and Laurian 2015 in France, Wong 2019 in Guangzhou and Taipei), but also in the more general case of polluting facilities.

Early reports of differential impacts of environmental pollution emerged in the US in the mid-1980s, paving the way for what would become the environmental justice movement and literature (e.g., US GAO 1983, UCCRJ 1987). Research, using increasing analytical sophistication, found plentiful international evidence that minorities are disproportionately impacted by toxic facilities (e.g., Bullard 1990, 1994, Bryant and Mohai 1992, Mennis 2003, Laurian 2008a,b, Agyeman *et al.* 2016); air pollution (e.g., Mitchell and Dorling 2003, Morello-Frosch, Pastor, and Sadd 2001, McLeod *et al.* 2000); transportation projects (e.g., Chakraborty 2006, Deka 2004); differences in environmental law enforcement (e.g., Mennis 2005); natural disasters and related risks; and the benefits provided by environmental goods, such as urban green spaces (Wolch, Byrne, and Newell 2014, Angelovski 2016, Schwarz *et al.* 2015).

In light of the controversial nature of incinerating facilities, and of the vast literature on environmental justice that shows that toxic sites tend to worsen the living conditions of the most deprived communities, this study explores the possibility that pairing desirable community amenities with polluting, industrial, or otherwise unwanted sites, such as waste incinerators, may mitigate or compensate for some of their negative local impacts. Despite the wealth of study on waste incinerators, little empirical research has explored the growing trend, in some incineration-dependent countries, for adding community amenities to waste incinerators. The citywide experiment in Seoul, South Korea illuminates the extent to which amenity features lessen the negative economic impacts of incinerators on surrounding urban areas. While incinerators have many negative environmental, health, social and psychosocial impacts, we focus here on their impacts on local land and housing values which capture, or reflect, social, perception and reputational impacts.

1.1. Mitigating public stigmatization: community amenities as a solution

Resulting from the known and perceived health effects, social stigmatization, negative impacts on property values, unfair siting decisions, and at times concerns about the possibility that incineration will discourage waste recycling and diversion, the siting of new incinerators is typically associated with public opposition in the West as well as in Asia. Public campaigns against incinerators emerged in the 1970s in the US (Rootes and Leonard 2009). They remain active in Canada (Baxter *et al.* 2016) and in Europe (e.g., Rootes 2009; Leonard, Fagan, and Doran 2009, McCauley 2009, Szarka 2002, Young 2007, Greenpeace France 2010, the Gaia network, i.e., Global Alliance for Incinerator Alternative). While new incinerators are still planned, they are becoming

increasingly difficult to site and some of these campaigns have successfully defeated projects. Recent opposition to incineration is also documented in China (Wong 2019, Li *et al.* 2016, Sun, Zhu, and Chan 2016, Johnson, Lora-Wainwright, and Lu 2018, Huang *et al.* 2015) in Japan (Nakazawa 2016, 2017, 2018, Hunsicker, Crockett, and Labode 1996), Taiwan (Wong 2019) and in South Korea (Jeon 2000).

Given this opposition, the idea of joining public goods with incinerators to mitigate negative public perceptions is gaining traction. The Vienna Spittelau incinerator was famously designed by Hundertwasser, adding visual interest to the neighborhood. Hunsicker, Crockett, and Labode (1996) document the addition of community centers to incinerators in Japan, Taiwan, and South Korea. In Chinam, Huang *et al.* (2015) recommend not only plant monitoring and strict emissions standards, but also improving road conditions when proposing new incinerators.

One can argue that associating public ‘goods’ with environmental ‘bads’ is a way to obtain the buy-in of communities and reduce opposition at low cost. On the other hand, these policies to add positive neighborhood amenities to incinerators (in addition to stringent emissions regulations) have the potential to mitigate the impacts of incinerators not only on health, but also on property values, neighborhood image, and overall quality of life for residents. While we cannot assess whether communities were coopted in the siting decision-making process, we can nonetheless answer the following question: *Does the addition of positive amenities, such as recreation centers, mitigate the negative impact of incinerators in local property values?*

We sought to answer this question using the South Korean case, one of the few countries that has built various types of community amenities on incinerator sites in metropolitan areas. In South Korea, the Seoul Metropolitan Area (SMA) hosts about 50% of the population, and 22 of its 49 solid waste incinerators are located within SMA. In 2013, nearly 2 million tons of waste were incinerated in these facilities, i.e., about 59% of the waste generated nationwide. These incinerators generate heat (1790 GJ) and electricity (120,000 Mwh) distributed to local communities at a discounted price or put back to the grid. Thirteen of these incinerators were built to include amenity features, such as parks, sports and recreation facilities such as swimming pools, gyms, and community centers, thus potentially transforming them into community assets. Thus, South Korea makes an excellent case for investigating the role of positive amenities on surrounding communities. The next section further provides the context of building community amenities in SMA.

1.2. Making incinerators acceptable: the South Korean approach

The amount of waste production in Korea began to increase in the 1960s as the country went through rapid economic development. Over time, landfills, the primary waste management method in Seoul, began to present many issues. The major landfill within city limits (Nanji-do) constrained surrounding land uses and caused heavy truck traffic and foul odors. The South Korean government shifted towards incineration in the early 1990s, and built waste incinerators across the metropolitan area. Incineration was considered a preferable alternative in Seoul because waste can be processed within one to two days, does not require a large land mass and does not cause unpleasant odors. Furthermore, the heat energy generated by incineration contributes to the city’s energy supplies.

In Seoul, the land area for these incinerators was secured along with new residential development and the construction of New Towns around Seoul. The shift toward incineration was also accompanied by proactive waste management reduction strategies: volume-based waste disposal rates deployed in 1995, extended producer responsibility systems imposed in 2003, and restrictions on direct disposal of food waste added in 2005. These policies aim to increase recycling and reduce the total amount of waste. A similar policy, the Unit Pricing scheme, was also found to be effective in Spain (Weber *et al.* 2019). As a result, the average household solid waste production declined from 1.3 kg to 0.95 kg/day/capita between 1994 and 2012. As the amount of waste produced diminished, the capacity of incinerators exceeded the amount of waste generated in each district. For example, the Gangnam incinerator was built to process 900 tons of waste per day while its district (Gangnam-gu) rarely produces more than 300 tons of waste.

As a result, incinerators' service areas were expanded by the 2001 Regional Shared Use Policy: the four municipal incinerators in Seoul City (Gangnam, Nowon, Mapo, and Yangcheon) process the waste generated from 22 of the 25 municipal districts, or *gu* (Shin and Huh 2017). Similar agreements were reached among the municipalities in Gyeonggi Province and Incheon City to extend the coverage of the 18 incinerators to include all municipalities in the Seoul Metropolitan Area (Korea Waste Association 2014).

Overall, in the Seoul Metropolitan Area, the successful waste reduction from implementing stringent recycling, composting, volume-based waste pricing (i.e., Unit Pricing) policies contributed to reducing the number of incinerators in the region. In Mallorca, Spain, waste reduction from Unit Pricing policies led to incinerator overcapacity, affecting the profits of the operating entities (Weber *et al.* 2018). In contrast, in the Seoul Metropolitan Area, regional inter-municipal agreements enabled the optimization of incinerator capacity and avoided over building incinerators. The 22 metropolitan area incinerators are managed by 21 municipal governments, which have commissioned the operation of the facilities to a combination of public and private entities (two incinerators are located in the same municipal district *Yongin-Si*).

In 2013, about 25.3% of household solid waste was incinerated, 59.1% was recycled and 15.6% was landfilled in Korea nationwide (Kim and Park 2015). Seoul has four incinerators in operation, each processing over 400 tons of waste per day, with 18 more in the wider Seoul Metropolitan Area. Incinerator construction started in the early 1990s and was not without controversy. In Seoul, only four of the eleven planned incinerators were built, not only because of successful waste reduction efforts but also because the service areas of incinerators were expanded beyond their district. These regional expansions resulted from long deliberative processes ranging from one to nine years. During the entire fourteen-year period of the four incinerators' design and construction (1992-2005), a total of 396 petitions were reported. Initially, residents opposed the construction of incinerators in their district because of economic, environmental, and procedural concerns (Jeon 2000). Residents argued that incinerators would negatively affect local housing values, as well as their health and well-being. They also called for transparency and participation in the design and construction process. A survey of public perceptions of incinerators found negative perceptions of the impacts of incinerators on air quality, odor, noise, traffic congestion, sunlight disturbance from the smokestack, and community reputation (Institute for Environmental Research 2013).

In response to residents' opposition, the municipal government implemented multiple strategies. First, local authorities sought to transform the negative image of waste management facilities. Following national government's lead, they replaced waste-related terms with environmentally friendly expressions, such as "resource recovery facilities" instead of "household waste incinerators," and "environment stabilization facilities" instead of "landfills." These new terms were expected to mitigate opposition and promote the positive impacts of incinerators.

Second, local authorities collected and incorporated residents' input from the initial stage of incinerator siting to the ongoing management of incinerators. Resident participation is especially important given the high population density in Seoul. Multiple strategies were used to encourage participation and cooperation from residents near each facility. For instance, the Gyeonggi provincial government provided individualized financial incentives and organized a neighborhood watch commission to monitor incoming waste streams. The purpose of the commission is to prevent toxic emissions and protect public health.⁴ Commission members randomly select and inspect garbage trucks operated by the municipal governments, and if moisture, food waste or toxic materials are found in the incoming garbage, these trucks are prohibited from entering the facilities. Commission members work during the incinerator's operating hours and are financially compensated for their contribution. The city government also provides free annual health examinations for residents, which tests the level of dioxins and heavy metals in residents' blood, as well as their general physical and mental health. Thus far, no specific impact has been identified through these tests.

In addition to these benefits, municipal governments offer community-based incentives to hosting districts. In Seoul, a fund was created to subsidize various utilities for residents around incinerators,⁵ including heat, Homeowners Association (HOA) fees, rent, reduced user fees for community amenities, as well as health examinations. According to Shin and Huh (2017), from 1996 to 2013, a total of 170 billion Won (appr. \$155 million) was spent on subsidizing affected residents, about \$12,000 per household.⁶ Community amenities are the prime example of these local-based incentives. The Guri City incinerator, in the Gyeonggi province, has an observatory on its smokestack, and a community sports complex around the incinerator, including baseball courts, a soccer field, a sauna, etc. During siting processes, the municipal government invited local communities to host incinerators and reap related economic benefits. In municipalities outside Seoul that have been experiencing population decline and aging, local residents tend to welcome the financial incentives and community amenities that accompany incinerators. Residents can also expect a short-term increase in local employment when incinerators are constructed. These benefits can outweigh the potential negative impacts of incinerators, such as air quality and health effects. For instance, Jeonju City government (in the North Cheolla province) ran an open bid in 2000, in which four municipalities participated and one was selected.⁷

It is important to note that municipal governments incorporate local residents' participation and input *prior to* incinerator construction. The municipal governments in South Korea were able to minimize frictions with local communities by providing tangible and immediate financial benefits and by ensuring transparency in the siting and construction processes. For instance, in expanding the regional coverage of the Gangnam incinerator to adjacent districts, the city government proposed to offer 7.7 billion Won (approximately seven million dollars) to the residents of Gangnam-gu.

Residents can form their own committee to determine the distribution of this fund. Furthermore, resident committees can exercise veto power on various issues, including the selection of the experts in charge of Environmental Impact Studies and of members of neighborhood watch commissions, and determining the level and scope of compensation for nearby impacted areas⁸ (National Legislation 17-2 regarding Waste Management Facility Construction and Community Support).⁹ This integrative approach mitigates some of the residents' concerns about the impact of incinerators on housing values, and local health and wellbeing. This extensive community engagement process achieves some level of procedural justice during the siting and operation of incinerators.

However, some disputes, complaints, and anxieties remain about the safety and siting equity of incinerators. In this context, linking incinerators with community amenities stands as a viable contribution to the general welfare of affected areas, and is free from legal disputes. Furthermore, they have the potential to prevent property value depreciation, which we explore in detail in this article.

1.3. Emission standards, amenity features, and energy production for waste incinerators

In addition to resident compensation and involvement, the South Korean national government has improved emission standards and waste management processes since the late 1990s. In 1997, recognizing the health impacts of dioxins emitted by incinerators, the South Korean government lowered the maximum emissions standard to 0.1 ng-TEQ/Nm³ for newly built incinerators and 0.5 ng-TEQ/Nm³ for incinerators built prior to 1997. The incinerators built prior to 1997 had until 2003 to upgrade their facilities and comply¹⁰ (Kim *et al.* 1999). Na (2003) provides an overview of the changes in the air quality management policies of South Korea. Of all the regulated air pollutants under the Air Quality Management Act, only six ambient air pollutants from waste incinerators are publically reported: carbon monoxide (CO), hydrochloric acid (HCl), sulfur oxide (SO_x), nitrogen oxide (NO_x), dust particles, and dioxin. Other air pollutants such as hydrogen cyanide (HCN), bromic acid, benzene (C₆H₆), and phenol (C₆H₅OH), mercury (Hg), arsenic (As), vinyl chloride, and heavy metals (e.g., Cd, Pb, Cr, Ni, Zn) are regulated under the enhanced Air Quality Management Act, but actual emission levels are not included in publicly reported emission data.

These stringent standards may be bearing fruit since a recent health impact assessment conducted by the Institute for Environmental Research at Yonsei University in 2013 shows that health outcomes near waste incinerators in Seoul City were not significantly different from those in areas unaffected by incinerators. When testing for heavy metals, dioxins and chemical compound residuals in residents' blood around the four incinerators in Seoul, dioxin concentrations were insignificant, and the concentrations of cadmium (Cd) and mercury (Hg) were within the World Health Organization (WHO) standards – except for one individual in Yangcheon District who showed a high concentration of cadmium and four people in Gangnam District showing a high concentration of mercury (Institute for Environmental Research 2013). On the other hand, a study of the health impacts of sludge incinerators conducted by Park, Choi, and Park (2011) showed that toxic exposures for nearby populations were at about the same level as incinerator workers. This suggests that the current emission standards might not be effectively protecting public health.

As shown in Table 2, the monitored emissions of SO_x, NO_x, HCl, CO, dust particles, and dioxin in 2013 from all 22 incinerators in the Seoul Metropolitan Area did not exceed the limits set by the enhanced emission standards.

Kim *et al.* (1999) note that, in the late 1990s, only five out of seven incinerators in Seoul Metropolitan Area produced heat and electricity which were distributed to the communities and used by the facilities themselves. In the policy recommendation report to the Ministry of Planning and Budget, Kim *et al.* (1999) recommended reutilizing the energy produced from waste incinerators. As a result, by 2000, 19 out of the 22 incinerators in the Seoul Metropolitan Area were producing heat and eight of them were producing electricity (Korea Waste Association 2014).

Thirteen waste incinerators in the SMA are equipped with community amenity features such as swimming pools, gyms, golf ranges, outdoor soccer fields, and parks onsite (See Figure 1). The Youth Center of Nowon Incinerator is located right next to the incinerator structure (left photo in Figure 1), and the community recreation center of Icheon Incinerator is located right across from the incinerator (right photo in Figure 1). The Gangnam, Yangcheon, and Nowon incinerators in Seoul City and Gwangmyeong incinerator in Gyeonggi Province went through considerable design upgrades around the late 2000s to make the facilities more aesthetically appealing (see Figure 1). Similar to Minato Incineration Plan in Osaka, Japan, and Beito Refuse Incineration Plan in Taipei, Taiwan, Guri Incinerator in Gyeonggi Province has an observatory deck which has become a community landmark.

While studies of the impacts of incinerators on property values in different housing markets found that incinerators depreciate local property values (e.g., Zuideau and Letombe 2008, Farber 1998), the 2013 survey of public perception of incinerators by the Institute for Environmental Research (2013) found that communities' perceptions of incinerators' impacts on land price and housing value were insignificant. This suggests incinerators in Seoul may have minimal effects on the real estate market, possibly resulting from the enhanced emission standards and amenity features. Thus, it is possible that waste incinerators in the SMA have been transformed from Locally Unwanted Land Uses (LULUs) to community assets with minimal socio-economic impacts.

2. Conceptual framework and hypothesis

The literature includes few studies that quantify the socioeconomic effects of incinerator upgrades and emission standard enhancements. Therefore, we seek to address this research gap by conducting a series of quantitative analyses. Based on the existing literature, we hypothesized that areas surrounding incinerators without positive amenities may see population and property values decline after the incinerator is sited, while property values near incinerators with amenities decrease less, or not at all. Thus, the core hypotheses of this study are as follows:

Population decline hypotheses (H1): *Population will decline faster in communities with incinerators than in communities without incinerators (H1a) and in communities with incinerators without amenities than in those with incinerators with amenities (H1b).*

Property value decline hypothesis (H2): *Property values will decline in communities with incinerators compared to communities without incinerators (H2a). In communities with waste incinerators, the decline in the property values will be greater in communities without amenities than in those with amenities (H2b).*

Table 1. Enhanced air pollutant emission standards between 1991 and 2005.

Air pollutants	Emission standards			
	1991-94	1995-98	1999-2002	Enhanced Standards to be applied in 2005
CO (ppm)	600	600	600	Incinerator Capacity > 2tons/hour 2tons/hour > Incinerator Capacity > 200kg/day Incinerator Capacity < 200kg/hour
HCl (ppm)	80	60	50	Incinerator Capacity > 2tons/hour: 2tons/hour > Incinerator Capacity > 200kg/day Incinerator Capacity < 200kg/hour
SOx (ppm)	300	300	300	Incinerator Capacity > 2tons/hour: 2tons/hour > Incinerator Capacity > 200kg/day Incinerator Capacity < 200kg/hour
NOx (ppm)	400	400	400	Incinerator Capacity > 2tons/hour: 2tons/hour > Incinerator Capacity > 200kg/day Incinerator Capacity < 200kg/hour
Dust (mg/Sm ³)	100 200	80 100	80 100	Incinerator Capacity > 2tons/hour: 2tons/hour > Incinerator Capacity > 200kg/day Incinerator Capacity < 200kg/hour
				2tons/hour > Incinerator Capacity > 200kg/day
				200

(Continued)

Table 1. (Continued).

Air pollutants	Emission standards			
	1991–94	1995–98	1999–2002	Enhanced Standards to be applied in 2005
Pb (mg/Sm ³)	10	10	5	Incinerator Capacity < 200kg/hour
				Incinerator Capacity > 2tons/hour:
				2tons/hour > Incinerator Capacity > 200kg/day
				Incinerator Capacity < 200kg/hour
Cd (mg/Sm ³)	1.0	1.0	1.0	Incinerator Capacity > 2tons/hour:
				2tons/hour > Incinerator Capacity > 200kg/day
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
Cr (mg/Sm ³)	1.0	1.0	1.0	Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
Cu (mg/Sm ³)	10	10	10	Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
Ni (mg/Sm ³)	20	20	20	Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
Zn (mg/Sm ³)	10	10	10	Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
Dioxin (ng-TEQ/Nm ³)	Did not exist	0.50 ng-TEQ/Nm ³ for the existing incinerators built prior to 1997	0.10 ng-TEQ/Nm ³ for newly built incinerators since 1997	Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour
				Incinerator Capacity < 200kg/hour

Source: Na (2003), Kim et. al (1999).

Table 2. Waste incinerators in Seoul metropolitan area (2013).

Municipal government	Capacity		Date started operation	Amenities		Monitored emissions in 2013						
	Incinerators	units		Parks	Sports Rec Facility	SOx (ppm)	NOx (ppm)	HCL (ppm)	CO (ppm)	Dust (mg/Sm ³)	Dioxin (ng-TEQ/Nm ³)	
Seoul City	Gangnam-Gu	300	3	○	○	0.64	38.99	8.94	23.03	4.37	0.000	
	Nowon-Gu	400	2	○	○	1.64	45.40	0.80	9.97	4.04	0.008	
	Mapo-Gu	250	3	○	×	1.24	62.48	2.58	5.88	1.34	0.007	
Incheon City	Yangcheon-Gu	200	2	○	○	0.92	44.24	3.83	14.55	2.22	0.003	
	Jung23-Gu	70	2	×	×	0.32	12.47	2.01	11.90	2.73	0.002	
	Yeonju-Gu	210	2	×	○	2.87	42.43	5.33	13.73	1.17	0.004	
	Seo-Gu	210	2	○	○	1.06	67.01	1.10	16.89	2.10	0.014	
Gyeonggi Province	Ansan-Si	200	1	×	×	0.27	28.74	0.50	5.48	1.61	0.005	
	Anyang-Si	200	1	×	×	—	17.98	5.82	4.40	2.20	0.020	
	Bucheon-Si	300	1	○	×	—	27.64	2.73	11.55	2.42	0.000	
	Euijeongbu-Si	100	2	×	×	1.62	51.26	6.78	20.08	4.91	0.003	
	Goyang-Si	150	2	○	×	4.39	33.92	5.75	24.96	2.52	0.026	
	Gwacheon-Si	80	1	×	×	1.01	33.97	2.16	3.71	0.86	0.004	
	Gwangmyeong-Si	150	2	×	×	2.01	59.22	4.01	15.83	2.94	0.057	
Seoul metropolitan area	Guri-Si	100	2	×	○	3.08	70.05	8.16	15.67	4.81	0.028	
	Gunpo-Si	200	1	×	×	1.29	15.68	1.74	1.33	3.86	0.000	
	Icheon-Si	150	2	○	○	0.23	57.34	3.03	3.55	5.11	0.009	
	Paju-Si	100	2	×	○	2.06	79.04	10.12	6.39	2.33	0.002	
	Seongnam-Si	300	2	×	○	1.70	51.85	1.38	10.02	4.84	0.003	
	Suwon-Si	300	2	×	○	0.75	84.90	3.65	28.55	7.15	0.000	
	Yongin-Si Cheoin	300	3	×	×	3.28	90.30	1.59	47.36	2.44	0.042	
	Yongin-Si Suji	35	2	×	×	3.85	63.52	3.22	13.82	1.14	0.087	

Source: Korea Waste Association (2014).

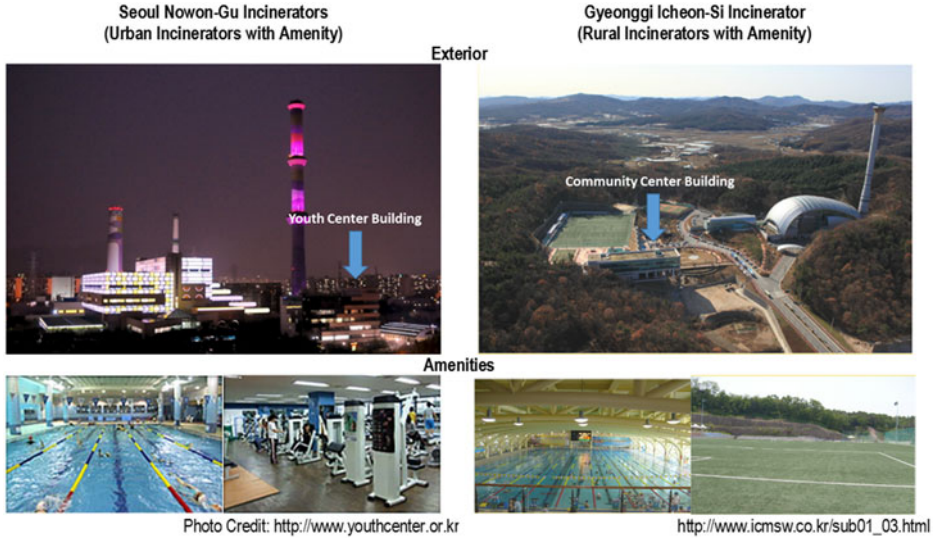


Figure 1. Exterior and amenity features of incinerators.

Figure 2 shows the conceptual framework of this research designed to test our main hypotheses. The modeling framework is discussed in the methodology section.

3. Research design and methodology

Our study area, the Seoul Metropolitan Area (SMA), consists of two metropolitan cities, Seoul City and Incheon City, and one Province, Gyeonggi Province. The SMA hosts about 50% of the South Korean population and 22 of its 49 incinerators. Four incinerators are located in Seoul City, two in Incheon City and the rest in Gyeonggi Province (see Figure 3). In 2013, the 22 incinerators in the entire region processed about 2.03 million tons of solid waste (about 59% of the waste generated nationwide) – the four incinerators in Seoul City processed 778,000 tons, three incinerators in Incheon City processed about 278,000 tons, and the rest of the 14 incinerators in Gyeonggi Province processed 972,000 tons (Korea Waste Association 2014).

The metropolitan cities consist of municipalities called “Gu”, and the province consists of “Si” and “Gun” all of which have their own elected form of government. The 66 municipalities, hereafter noted as the Census Districts or Districts, are our unit of analysis. These are the smallest geographical units for which the census data were available. The 22 incinerators are located in 21 independent Districts, making it possible to join the incinerator information to census data. Yong-In district has two incinerators one in a rural community and the other in an urban community.

To get a general sense of the land use surrounding incinerators, we collected 2012 Land Use data from the South Korean National Open Data Portal (South Korea Ministry of the Interior and Safety and National Information Society Agency 2018). We analyzed the land use mix (e.g., residential, commercial, industrial, agricultural, and green space) within a 4 km radius from each incinerator. Similarly, Candela *et al.* (2015) defined a 4 km radius from the municipal waste incinerator as the health impact zone. As shown in Table 3 and Figure 4, the land use mixes around incinerators vary

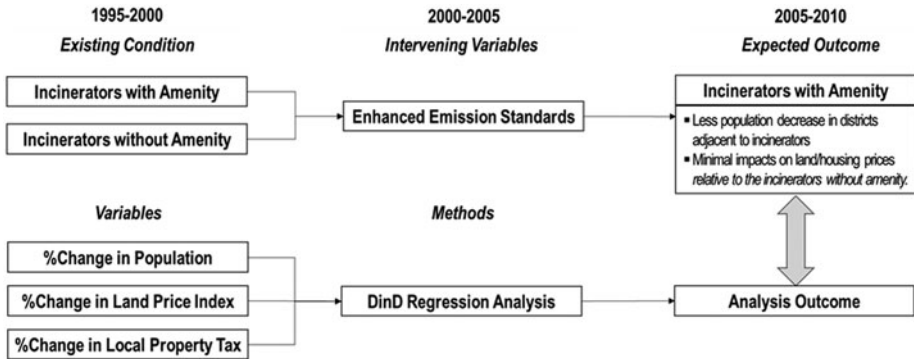


Figure 2. Conceptual framework.

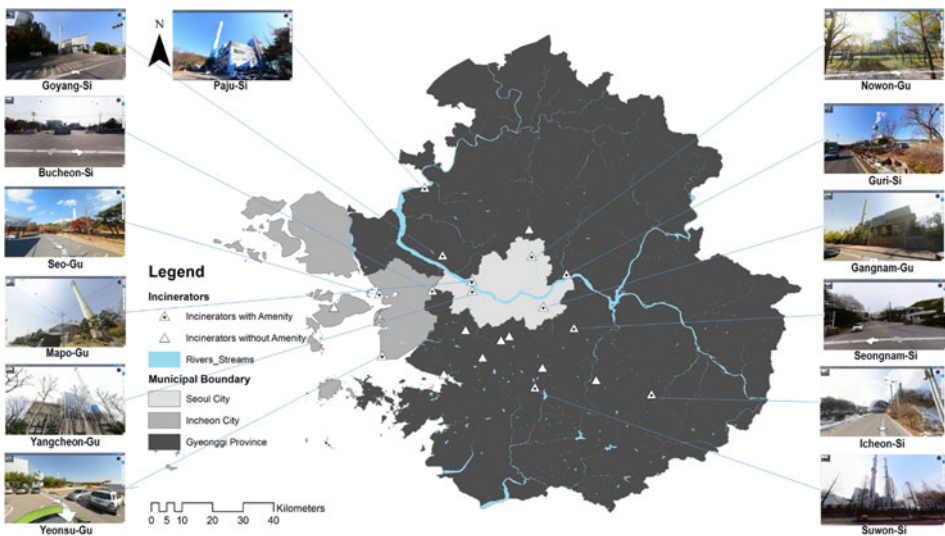


Figure 3. Location of incinerators in the Seoul metropolitan area and exterior photos of incinerators with amenity taken from Naver street view.

by municipalities. The four incinerators in Seoul City are predominantly surrounded by residential areas (red) and green spaces (green), whereas those in Gyeonggi provinces have a higher portion of green and agricultural areas. Of the five land use categories, residential use and green space are the two major land uses around the incinerators in the study area. The rural municipalities of Gyeonggi Province, Icheon-Si, Gunpo-Si, and Paju-Si, showed a higher percentage of agricultural areas around incinerators (67.0%, 78.5%, and 80.9% respectively).

We examined reports disclosing each incinerator's emission data, operation revenue, and expenses, and volume of incinerated waste published by the municipal governments and the South Korean Ministry of Environment (Korea Waste Association 2014; Institute for Environmental Research 2013). For the incinerators that did not have sufficient information online, we used Naver Street View from online map Naver Map (equivalent to Google Street View) to examine whether the facilities have community

centers and parks. The features identified were coded as a binary variable and associated with the locational data for the incinerators joined to the census boundaries.

To test our hypotheses, we collected census data covering the periods before and after the stricter emission standards were adopted. As described in Table 1, the emission standards for incinerators were enhanced since 2005, enabling us to define the before-after periods of policy implementation. 1995-2000 represents the ‘before’ period and 2005-2010 represents the ‘after’ period. In order to calculate the changes in the dependent variables (population, property taxes, land values) between these periods, the census boundaries for 2000, 2005, and 2010 were unified to match the 1995 boundaries.

The dependent variables include the percent change in Land Price Index to examine the effect of the incinerators on land markets, the percent change in local property taxes to examine the effect on the real estate market, and the percent change in population to analyze the effects on the demand for living in the areas with and without incinerators, and in areas with incinerators with and without amenities. The Land Price Index was calculated based on the Laspeyres Price Index method and reflects the relative changes in land price referenced to 2014 land prices. Actual housing prices for our study area and study periods were unavailable from the Korean census bureau. Lee (2007) found that, in South Korea, the local property tax rates between 1989 and 2005 were highly correlated with the housing transaction costs in South Korea. Therefore, the percent change in local property tax per household can be used as a proxy for measuring the effects of incinerators on housing price. In order to control for the effects of density on the property tax collected, we normalized the variable by dividing it by the total number of households in each census district. Han (2017) used the same variable to measure the effects of greenbelt relaxation policy on housing prices.

We employed a Difference-in-Differences (DinD) model to establish a causal inference between the policy change (enhancement of emission standards), incinerator amenity features, and the dependent variables. The DinD research design is often used for evaluating policies or programs (Meng, Hsu, and Han 2017; Imbens and Wooldridge 2009; Duflo, Glennerster, and Kremer 2006; Gelman and Hill 2006; Gelman 2004). In the regression models, the locational dummy variables classifying the Districts with different types of incinerators were included to interact with the treatment variable, Before-After, i.e. (1) for the period between 2005 and 2010 after the emission standard enhancement and (0) for the period between 1995 and 2000 before the policy change. The locational dummy variables include (1) Districts with incinerators with amenities classified as the treatment group, (2) Districts with incinerators without amenities classified as the first control group, and (3) Districts without incinerators classified as the second control group of counterfactuals (see Table 4).

The equation for the DinD using the key variables listed in Table 4 is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 T + \beta_4 X_4 * T + \beta_5 X_5 * T + \beta_n X_n + \varepsilon \quad (1)$$

CHANGE	Districts with Incinerators with Amenity (Treatment)	Districts with Incinerators without Amenity (Control 1)	Districts without Incinerators (Control 2, Counterfactual)
Before	$\beta_0 + \beta_1$	$\beta_0 + \beta_2$	β_0
After	$\beta_0 + \beta_1 + \beta_3 + \beta_4$	$\beta_0 + \beta_2 + \beta_3 + \beta_5$	$\beta_0 + \beta_3$

Table 3. Land use mix and incinerators.

Metro area	Census districts	Total Area	Land uses				Green			
			Residential	Commercial	Industrial	Agricultural				
Seoul City	Gangnam-Gu	50.2	27.2	54.2%	2.9	5.8%	0.0	0.0%	20.1	40.0%
	Mapo-Gu	24.1	9.5	39.4%	0.5	2.0%	0.6	2.5%	0.0	56.1%
	Nowon-Gu	50.2	31.9	63.5%	1.2	2.4%	1.2	2.5%	0.0	31.7%
Incheon City	Yangcheon-Gu	50.0	24.3	48.5%	2.9	5.8%	6.1	12.1%	0.0	33.6%
	Jung23-Gu	34.8	4.1	11.9%	0.7	2.0%	3.1	9.0%	0.0	77.2%
	Seo-Gu	28.0	3.8	13.6	2.0	6.9%	6.3	22.4%	0.0	57.0%
Gyeonggi Province	Yeonsu-Gu	11.5	3.6	31.7%	0.1	0.5%	2.0	17.5%	0.0	50.4%
	Ansan-Si	46.6	8.8	18.9%	1.7	3.7%	9.3	19.9%	0.0	57.5%
	Anyang-Si	50.2	14.5	28.9%	2.2	4.4%	3.4	6.7%	0.0	59.9%
	Bucheon-Si	50.2	11.1	22.1%	0.8	1.7%	3.6	7.2%	0.0	69.1%
	Euijeong-Si	50.2	11.4	22.6%	1.5	3.0%	0.4	0.8%	0.0	73.6%
	Goyang-Si	45.0	11.9	26.4%	2.4	5.4%	0.0	0.0%	3.9	59.5%
	Gunpo-Si	49.7	8.5	17.1%	0.6	1.3%	1.6	3.2%	0.0	78.5%
	Guri-Si	50.2	13.8	27.5%	1.2	2.4%	0.1	0.2%	0.0	69.8%
	Gwacheon-Si	19.7	1.4	7.1%	0.0	0.2%	0.0	0.0%	0.0	92.8%
	Gwangmyeong-Si	50.2	13.9	27.6%	2.2	4.5%	0.8	1.6%	0.0	66.3%
	Icheon-Si	31.3	0.0	0.0%	0.0	0.0%	0.0	0.1%	22.0	32.8%
	Paju-Si	19.5	0.7	3.3%	0.1	0.4%	1.6	8.1%	15.7	7.3%
Seoul City	Seongnam-Si	44.2	7.7	17.3%	0.8	1.7%	1.5	3.4%	3.3	70.1%
	Suwon-Si	50.0	18.4	36.8%	2.7	5.3%	4.3	8.6%	0.6	48.1%
	Yongin-Si Suji	46.3	14.8	31.9%	1.6	3.4%	0.0	0.0%	0.0	64.6%
	Yongin-Si Cheoin	49.4	1.4	2.8%	0.1	0.2%	0.0	0.0%	2.5	91.9%

Source: Data processed by the author using 2012 Land Use data provided by www.data.go.kr.

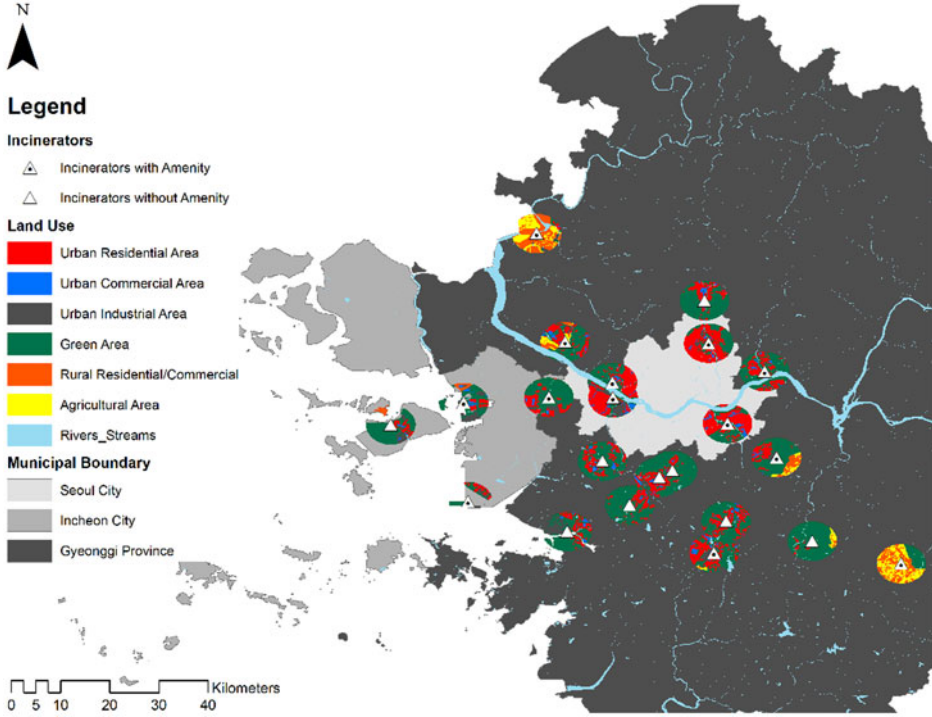


Figure 4. Land use mix around incinerators.

where Y denotes the dependent variables; X_1 is an indicator variable for incinerators with amenities; X_2 is an indicator variable for incinerators without amenities; T is an indicator variable for the periods after the emission standard was implemented; $X_1 * T$ is the interaction term between X_1 and T ; $X_2 * T$ is the interaction term between X_2 and T ; X_n stands for other explanatory variables; and ε is the stochastic error term. The estimated coefficient β_4 measures the isolated effects of stricter emission standards on the Districts with incinerators with amenity; β_5 measures the isolated effects of stricter emission standards on the Districts with incinerators without amenity; and β_3 measures the isolated effects of stricter emission standards on the counterfactuals – the Districts without incinerators.

In addition to the main variables, a binary variable for New Towns was included to account for the effect of new town developments in the region as they were closely related to population growth, housing prices, and land value changes. Another binary variable, Seoul, indicates the Districts within Seoul City to account for the primacy of Seoul in the region and higher demands for housing in the city. As for the incinerators, incinerators that generate and sell heat and electricity were indicated as binary variables.¹¹

To analyze whether the effects of the enhanced emission standard on the treatment group were significantly different from the control groups, we tested the linear hypotheses using a Chi-Square test. The tested linear hypotheses are:

$$H_0: \text{Effects on Treatment Group } (\beta_4) = \text{Effects on Control Group 1 } (\beta_5)$$

$$H_0: \text{Effects on Treatment Group } (\beta_4) = \text{Effects on Control Group 2 } (\beta_3)$$

Table 4. Key dummy variables.

Groups		Groups			N
		X ₁	X ₂	X ₃	
Treatment	Districts with lower emission Incinerators with Amenity	1	0	0	13
Control 1	Districts with lower emission Incinerators without Amenity	0	1	0	7
Control 2	Districts without Incinerators (Counterfactual)	0	0	0	56

Initially, we used the Ordinary Least Square regression analyses for all of the three dependent variables. Spatial autocorrelations of residuals were detected when we performed the Moran's I test, meaning that the OLS models were missing spatially correlated variables (Anselin 2004). In order to correct for this, we employed Generalized Least Squares (GLS) models to incorporate the structure of the correlated errors and account for spatial autocorrelation. The best-fitting correlation structure was found to be exponential for all three models. The descriptive statistics for the variables used in the models are summarized in Table 5 below.

Prior to running the regression models, we examined the distribution of the changes in the dependent variables across the 66 census districts. The maps in Figure 5 show the standard deviation maps along with the locations of 22 incinerators in the SMA. As shown, it appears that the changes in the three dependent variables in relation to the locations of the incinerators were random during the study period.

4. Findings

Table 6 presents the results of the Difference-in-Differences regression models. First, with regards to population change, Model 1 shows that holding everything else constant, districts in Seoul City generally experienced slower population growth than the rest of the region. This is mainly caused by very high property values that shifted

Table 5. Descriptive statistics summary.

Variables	Before (1995-2000)				After (2005-2010)				N
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Continuous variables									
% Change in Population	0.07	0.16	−0.12	0.59	0.04	0.10	−0.11	0.37	62
% Change in Land Price Index	−0.10	0.04	−0.15	0.06	0.14	0.04	0.07	0.25	52
% Change in Property Tax per Household	0.68	0.53	0.12	2.77	−0.34	0.80	−1.00	2.41	66
Binary variables									
Districts with Incinerators with Amenity	0.197	0.401	0	1	0.197	0.401	0	1	13
Districts with Incinerators without Amenity	0.106	0.301	0	1	0.106	0.310	0	1	7
Before-After	0.000	0.000	0	1	1.000	0.000	0	1	66
Districts with Incinerators selling Heat	0.258	0.441	0	1	0.258	0.441	0	1	17
Districts with Incinerators selling Electricity	0.121	0.329	0	1	0.121	0.329	0	1	8
Districts in New Towns	0.227	0.422	0	1	0.227	0.422	0	1	15
Districts in Seoul City	0.379	0.489	0	1	0.379	0.489	0	1	25

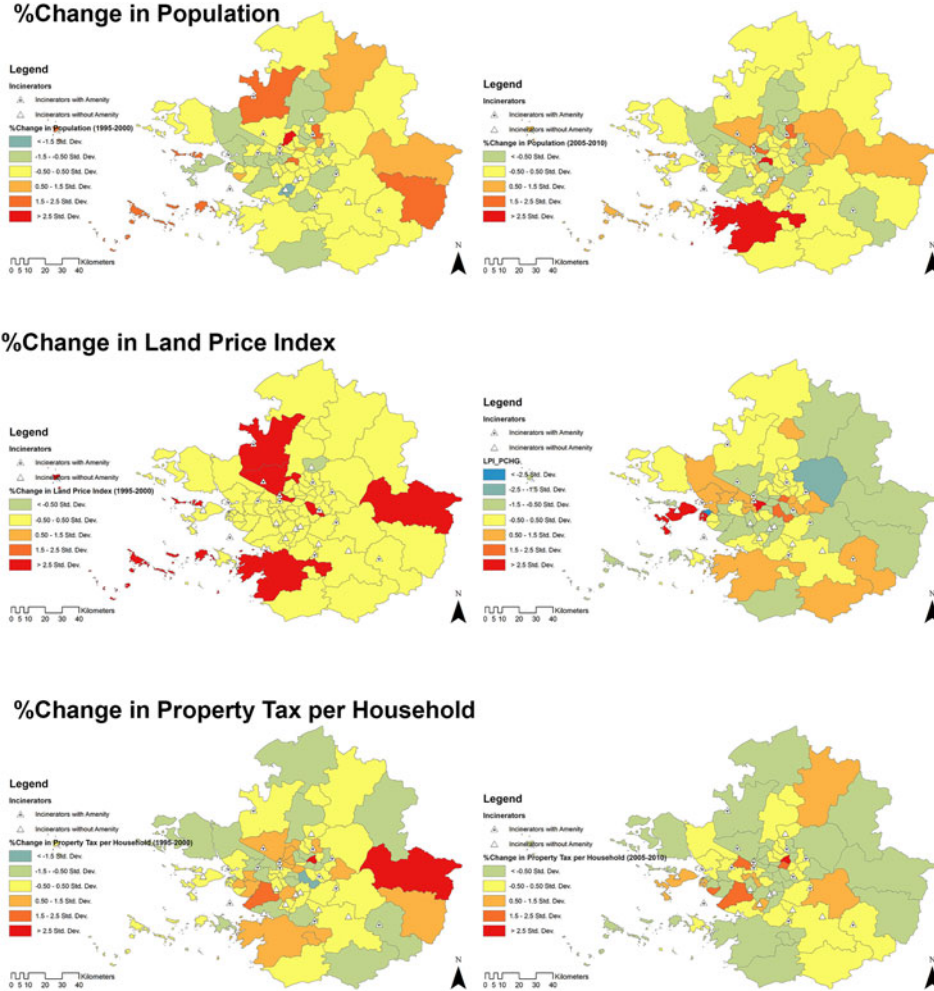


Figure 5. Standard deviation maps of dependent variables and the location of incinerators.

growth to outlying areas. Overall, the population change appears not to have been affected by the locations of incinerators. Thus, we rejected both of our hypotheses on population decline – *H1a: Population will decline faster in communities with incinerators than in communities without incinerators; and H1b: in communities with incinerators without amenities than in those with incinerators with amenities.*

Model 2 focuses on the impacts of incinerators, amenities and stricter emission standards on changes in property taxes. It shows that property taxes increased faster in Seoul City than in surrounding areas, which reflects the high and fast increasing property values in the City. After the policy changes occurred in the 2000s, the percent change in Property Tax per Household in the Districts that host incinerators *without* amenity features decreased by 30.7%. This decline can reflect a slower rate of increases in property values caused by the impact of these incinerators on local neighborhood reputation, desirability and housing markets. Homes may be more difficult to sell near incinerators that are essentially LULUs, and property values and taxes experience relative declines as a result. Whether caused by fiscal policies or real estate

Table 6. The transformation effects of incinerators.

Variables	Model 1 % Change in Population			Model 2 % Change in Property Tax per Household			Model 3 % Change in Land Price		
	Treatment: n = 26 Control 1: n = 14 Control 2 (Counterfactual): n = 84			Treatment: n = 26 Control 1: n = 16 Control 2 (Counterfactual): n = 90			Treatment: n = 22 Control 1: n = 14 Control 2 (Counterfactual): n = 68		
	Coeff.	Std. Err	p-value	Coeff.	Std. Err	p-value	Coeff.	Std. Err	p-value
(Intercept)	0.113**	2.547	0.012	0.984	1.540	0.524	-0.076***	0.022	0.001
District with incinerator with Amenity (dummy)	-0.002	-0.057	0.955	0.018	0.130	0.887	0.002	0.014	0.887
District with incinerator without Amenity (dummy)	-0.010	-0.162	0.872	-0.031	0.182	0.863	0.019	0.019	0.323
Before-After (dummy) (districts without incinerators)	-0.027	-0.434	0.665	-0.952	2.177	0.663	0.201***	0.031	0.000
Incinerators with Amenity* Before-After	-0.038	-1.031	0.305	-0.066	0.111	0.549	-0.002	0.012	0.836
Incinerators without Amenity* Before-After	-0.008	-0.143	0.887	-0.307*	0.173	0.079	-0.035*	0.019	0.064
Incinerators selling generated heat	0.005	0.112	0.911	0.077	0.125	0.537	0.001	0.014	0.963
Incinerators selling electricity	0.032	1.041	0.300	0.051	0.093	0.583	0.003	0.010	0.789
New Town Dummy	0.000	0.004	0.997	-0.022	0.077	0.774	0.000	0.008	0.971
Seoul City Dummy	-0.075**	-2.093	0.039	0.246**	0.113	0.031	-0.011	0.012	0.340
%Change in Population	-**	-	-	0.272	0.180	0.133	-0.019	0.020	0.333
AIC		-141.44			144.21			-326.85	
BIC		-108.61			183.35			-293.93	
Log likelihood		82.72			-58.11			176.43	
Chi-Square Test	χ^2	DF	p-value	χ^2	DF	p-value	χ^2	DF	p-value
Incinerators Amenity vs. No Incinerators	0.022	1	0.882	0.165	1	0.685	37.267***	1	0.000
Incinerators Amenity vs. Incinerators No Amenity	0.204	1	0.652	1.490	1	0.222	2.400	1	0.121

Note:

* $p < 0.1$.** $p < 0.05$.*** $p < 0.01$.

markets, Model 2 shows that incinerators without amenities have negative impacts on the local real estate market, as expected. In contrast, Districts with incinerators that have amenity features did not experience this relative decline in property taxes.

Model 3 explores the impacts of incinerators and policy changes on land prices. It shows that, overall, the percent change in land price increased by 20.1% in areas without incinerators in the 2000s compared to the previous decade. The subsequent Chi-Square test shows that the difference in the land price change in districts without incinerators is significantly different from those with incinerators with amenity. This means that when it comes to the impacts on land prices, districts are better off not having incinerators at all. In addition, as in Model 2, we see that after the emission standard enhancement occurred in the 2000s, the percent change in land prices decreased by 3.5% in Districts with incinerators without amenity features. This decline is not observed in districts that have incinerators *with* community amenities, suggesting that the amenities may be mitigating the negative impacts of incinerators on land values, compared to the districts with incinerators without amenities.

As observed in Models 2 and 3, the districts without incinerators experienced more rapid land price increases while those with incinerators without amenity features experienced a considerable decrease in property value represented by property tax. These findings support both of our hypotheses on property values – *H2a: Property values will decline in communities with incinerators compared to communities without incinerators; and H2b: In communities with waste incinerators, the decline in the property values will be greater in communities without amenities than in those with amenities.*

5. Discussion and conclusions

We studied the impact of incinerators with and without amenities on land and housing values in the Seoul Metropolitan area from the mid-1990s to 2010. While we found substantial negative effects of incinerators without amenities on local land and real estate markets, we do not observe any such impact in Districts with incinerators that have amenity features. Thus, we can infer that the amenity features of the incinerators along with enhanced regulatory policies are mitigating the negative economic impacts of incinerators.

This is an important finding, as it points to the ability of positive community amenities (parks, sports centers, etc.) to mitigate the negative economic impacts of incinerators, and potentially of other LULUs, on property and land values. This has interesting implications. First, if we focus strictly on property and land values, this finding indicates that an environmental ‘good’ can make up for a ‘bad.’ If amenities were added to all LULUs, local communities would reap some positive benefits, which could redress some levels of environmental injustice. In addition, in the US, EJ communities typically experience low property values, which makes it difficult, or virtually impossible, for residents who own their homes or who rely on low rents to move away from impacted areas. On the other hand, the Korean case shows that amenities help maintain property values. Where property values remain stable, residents who prefer to leave have the option to sell their homes. While incinerator amenities may not resolve environmental injustices because they do not reduce negative environmental impacts *per se*, securing local populations’ residential choices is one way to promote justice.

In addition, adding positive amenity features can facilitate equitable waste management facility siting by making incinerators acceptable to middle-to-high income

communities where concerns over property values are central to local opposition. This can promote a more equitable distribution of the burden of waste management facilities, thus contributing to environmental justice.

On the other hand, this idea raises important public health, ethical and socio-political dilemmas. First, adding recreational amenities does not diminish the air pollution and emissions-related health impacts of incinerators. While South Korean policies have dramatically reduced smokestack emissions, they remain non-null. In addition, truck traffic remains a correlate of incinerators, generating noise, dust and additional street-level emissions. There are consequences: health impacts are not addressed to the same extent that property values are, and if local populations spend more time near the incinerator (golfing, playing soccer, etc.), or are more likely to move near it as a result of the amenities, health impacts could worsen. The fact that population toxic exposures near sludge incinerators are at about the same level as incinerator workers (Park, Park, and Chang 2014) should make policymakers wary about further increasing the time residents spend in proximity to incinerators.

Second, the ethics of compensating an environmental bad by a good need to be investigated. Is it 'right' to add community amenities to compensate for the negative impacts of incinerators on health and property values? Does it amount to cooptation? Are local communities essentially 'bought' with relatively cheap compensatory mechanisms while still disproportionately bearing the negative health impacts of regional incinerators? Amenities are added to incinerators to limit or appease public opposition. Additional measures, e.g., community monitoring of incinerator and truck emissions to ensure that health impacts are minimal, can, and do, provide some level of community oversight. It is not clear to us how these community groups are performing these functions, or if they are effective monitoring and enforcement mechanisms. (This could be an area for future research.) However, in practice, incinerator emissions will not be null, and if emissions exceed health standards, the incinerator is unlikely to be closed because, once built, it remains a vital regional infrastructure.

Whether the addition of amenities to incinerators or other LULUs can, or should, be replicated elsewhere successfully will depend on emission controls, and on local socio-political forces that may value the net benefits of the amenities or, on the contrary, frame them as efforts to coopt neighbors and disempower legitimate opposition movements.

Finally, this study presents several caveats that need to be mentioned and that will also guide future research. We found that in the Seoul Metro area, districts that host incinerators (with and without amenities) do not lose or gain population at a different rate from districts without incinerators. It is thus unlikely that major long-term population shifts occur in response to incinerator siting. We did not explore the impact of each type of amenity, e.g., soccer fields, parks, swimming pools, etc. on land and property values. We also did not account for neighbors' perceptions of each site, of its potential health impacts, of how fairly or how well the community was treated or compensated for the incinerator location, or for the impact of waste garbage truck traffic. Investigating these topics will require further on-site visits, case studies and interviews with residents.

Notes

1. The most toxic, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,3 -TCDD) is recognized as a carcinogen by the EPA (Floret et al. 2003).

2. Ministerial Decree of September 20 2002. The 2000 European Directive also imposes standards for NO_x, SO₂, Particulate Matter and heavy metals.
3. South Korean government amended the Air Quality Management Act adopted in the 1990s in 2000 and started applying the enhanced standards in 2005.
4. If a garbage truck contains these elements, it is prohibited from entering the facilities, and the vehicle is temporarily banned.
5. The residents in the affected areas include those living within 300 meters of the site boundaries. As of 2013, a total of 12,637 households were counted as affected (Shin and Huh 2017).
6. Direct cash payment is not the primary means of compensating the affected residents, but there had been attempts by politicians to distribute cash. In 1999-2000, the district head of Ilwon-dong, the site for the Gangnam waste incinerator, gave \$1,600 to the residents in cash, arguing that there is no by-law that prohibits direct monetary compensation. However, it was highly criticized as political patronage (Gil 2001).
7. The open bid is particularly effective in small to medium-scale cities where the residents expect economic benefits from siting a waste incinerator (Cho and Lee, 2016). In Jeonju, the city government promised financial support for selected villages in the form of individual cash assistance, which appealed to local residents. Despite its voluntary nature, however, the open bidding may still generate conflicts between residents who support the siting decision and those who are against it. In one case, a group of residents filed a petition against the municipal government, stating that the government did not follow the original proposal and called for a complete withdrawal of the construction plan (Seo 2007).
8. The resident committee is formed from those living within 300 meters of the incineration facilities. Given the density of high-rise apartments, there are disputes over the physical boundary of the area, and members of the resident committee tend to negotiate on which buildings belong to the impact area and which do not.
9. For detailed information on residents' committees, see <http://www.law.go.kr/LSW//lsEfInfoP.do?lsiSeq=173599#>
10. The current dioxin emission standard for commercial and industrial solid waste incineration units in the US is 0.41 ng-TEQ/Nm³ (US EPA 2017).
11. Initially, the land use mix variables were included during the model fitting process. As the model including the land use variable did not show a good goodness-of-fit and insignificant coefficients, the variable was excluded from the final model.

Disclosure statement

No potential conflict of interest was reported by the authors.

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