# The Costs and Environmental Justice Concerns of NIMBY in Solid Waste Disposal

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**Abstract**

Many recent US Congresses have proposed bills that allow state and local governments to restrict interjurisdictional waste shipments. Using data on intercounty waste flows in California and a random utility model of haulers' decisions about where to deposit waste from each county, this paper studies the economic costs of import bans and import taxes and the implications on the distribution of waste disposal by race (and ethnicity). I find NIMBY-motivated laws would reduce intercounty waste transport at substantial economic costs. Furthermore, a NIMBY law enacted in a county, despite reducing the county's imports, could increase total intercounty waste in the whole state, generating additional external costs of transportation. A universal import ban in all counties would reduce transboundary waste but it would lead to substitution of waste away from facilities near white residents and toward facilities near Hispanic residents, exacerbating distributional concerns.

**Keywords:** solid waste, NIMBY, intercounty trash flows, distributional effects, environmental justice

**JEL Classification:** L98, Q52, Q53, Q56, Q58

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The term NIMBY (not in my backyard) describes the opposition to the proposed development of something considered undesirable and unwanted, such as prisons, sewage treatment plants, waste disposal facilities, and so on, in one's neighborhood. This paper considers the NIMBY phenomenon in solid waste disposal, whereby people oppose waste transporting to their local dumping sites. By solid waste or waste, I refer to the definition of municipal solid waste by the US Environmental Protection Agency (US EPA): the everyday waste type generated by residential, municipal, and commercial establishments such as product packaging, yard trimmings, furniture, clothing, bottles, cans, appliances, and so on. It does not include special-handling waste, such as waste from manufacturing processes, regulated medical waste, sewage, or hazardous waste.

Americans every year generate more than 200 million tons of such waste: in 2018, the total waste was nearly 300 million tons or 4.9 pounds per person per day.[1] The excessive generation of waste has brought immense challenges for state and local governments in handling and managing waste not only within but also from their jurisdictions. In fear of becoming a repository for waste from adjacent places and the dumping ground of the nation, several state and local governments have attempted to restrict waste imports. The 115th Congress (2017–2018) proposed the TRASH Act to authorize state and local governments to restrict interstate waste imports and impose a higher fee on out-of-state waste. This paper uses the case of intercounty waste shipments in California to illustrate the impacts of import bans and import taxes on the costs of discarding waste and the implications on environmental justice (specifically, the distribution of waste disposal by race).

Restricting transboundary waste transportation is not a new headline in the US. In fact, legislation that aims to allow controls on interjurisdictional waste has been considered in almost every Congress since 1990.[2] These immense efforts aim to reverse the Supreme Court's decisions that repeatedly overturned the local ordinances that restricted interjurisdictional waste flows. The Court has considered waste an ordinary commodity (*Philadelphia v. New Jersey*, 1978) and overturned the local restriction attempts on the basis that they discriminated against interstate commerce. The industry also reasons that its waste shipments are economically efficient, because wide differences in disposal fees at different waste disposal facilities justify incurring transportation costs.

Therefore, this paper evaluates the fundamental economic incentives underlying the waste shipments: the price-distance tradeoff. Using a random utility model, I model haulers' decisions about where to deposit the collected waste to minimize their costs of discarding waste. The model provides estimates for a hauler's willingness to pay for transporting waste as well as its preference

[1] I refer to short tons unless specified otherwise. Latest statistics are reported by the US EPA on its website. Access was retrieved in May 2022.

[2] By Congressional Research Service (2003); Thomson (2009) and supplemented search using the Library of Congress. Between the 101st (1989-90) and the 110th (2007-08) Congresses, 159 bills on restricting interjurisdictional waste flows were presented. After 2008, Congresses 2009-10, 2011-12 (to stop Canadian waste), 2015-16, 2016-17, and 2017-18 proposed similar bills.

regarding disposal fees paid to a disposal facility, transport distances, and the facility quality (captured by facility fixed effects). Given the primitives on how the hauler values those factors in its costs and how it decides where to haul waste to, I can quantify the counterfactual waste shipments if an import ban or tax were to be imposed.

A challenge in the estimation is to provide a consistent estimate for the price coefficient. Price is endogenous, because it is correlated with other facility quality that is unobserved by an econometrician and not controlled in the estimation. The price variable may also have measurement error, because I observe listed prices vis à vis contracted prices. To address these issues, I instrument for a facility's price in a county by total generated waste amounts (market sizes) of other nearby counties (markets). This instrumental variable (IV) is correlated with the facility's price in a specified county due to the (dis)economy of scale of the facility. For example, suppose the facility has an economy of scale. The facility will likely charge low disposal fees (without reducing its markup) when receiving a lot of waste from its surrounding markets. If a hauler is in a county that is near other counties that generate a lot of waste, it will likely face lower prices at the facility that serves all these counties. In short, the IV exploits the exogenous variation in the amount of waste generated by households to identify the price coefficient. This IV makes use of the available data on market sizes (total generated waste amount), which is often not observed and has to be estimated in the literature on industrial organization. This IV is also more effective than using the conventional instruments in the industrial organization literature in this context, because it has substantial variation over time, compared with BLP instruments (Berry et al., 1995), and it does not suffer from measurement error if observed prices have measurement errors, compared with Hausman instruments (Hausman, 1996; Nevo, 2001).

With the estimated coefficients underlying the haulers' choices of facilities, I quantify the impacts of import bans and taxes on out-of-county waste in California (henceforth, NIMBY laws). Results show the current intercounty waste flows are not only motivated by relatively low disposal prices in some disposal options outside the county of waste origin, but also by other benefits beyond disposal prices and transport costs. These benefits are associated with facility features such as high capacity, flexible operation hours, high acceptance rates, and so on. Hence, a NIMBY law would impose economic costs on haulers, by rerouting disposal to more expensive facilities or giving up the other benefits at previously preferred facilities. For example, a ban on intercounty waste transportation in California would increase the costs of discarding waste by \$4.6/ ton. If these additional costs were passed to households by haulers in the waste-collection process, households in a county would need to benefit \$276/ton of import reduction to break even on costs.

Besides the increase in the cost of discarding waste, the NIMBY law could *increase* total intercounty waste in California, despite the import reduction in the NIMBY-enacting county. The reason is the facilities in the NIMBY-enacting county could raise their prices to cover the higher marginal costs due to the loss in waste received and economies of scale. The price increase would harm local haulers and induce waste from the NIMBY-enacting county to export to other counties. Facilities in other counties would also change their prices, thereby altering the export-import composition in these counties, even though these counties may be over 100 miles away from the NIMBY-enacting county. Although some counties could benefit from the change in prices, the overall increase in total intercounty waste would incur extra waste miles traveled and associated external costs of transportation. Of course, NIMBY laws would limit total intercounty waste when all counties impose the rule together. However, as mentioned, the reduction in imports would incur additional costs of discarding.

These results add to previous studies that address interjurisdictional waste-flow controls. In the hazardous waste market, Levinson (1999a,b) find interstate waste taxes decrease shipments of waste to states with high taxes, and provide an estimate of the tax elasticities. In the solid waste market, Ley et al. (2000, 2002) show limitations on the size of shipments could increase the number of shipments, because states would export smaller volumes to more destinations. They characterize the state planner's intertemporal allocation of waste disposal and simulate the counterfactual results using aggregate data at the state level and other studies' estimates of transportation costs and demand elasticity, assuming the demand for waste disposal services is linear and the market is in a competitive equilibrium.[3] My model provides estimates of transportation costs and primitive coefficients that underlie the haulers' decision about where to dispose of waste to uncover the effects of interjurisdictional trade barriers in the presence of market power in the industry. The model accounts for the imperfectly competitive nature of the industry, because waste disposal is a differentiated service in price and in transport distance.

This paper also contributes to the literature on environmental justice (EJ) by being the first to address the racial distribution of waste *shipments* and the implications of NIMBY laws on this distribution. Solid waste distinctly differs from other nuisance cases, because waste may be legally moved by people. Hence, two EJ perspectives happen in the solid waste industry. One is the exposure to the presence of a facility. Previous studies have focused on this perspective by comparing the demographic composition between a nearby exposed neighborhood and areas that are far away and/or between the period before and after the facility appears; for example, see Baden and Coursey (2002), Mohai and Saha (2007), Banzhaf and Walsh (2008), and Wolverton (2009). However, a waste disposal facility is needed and has to be built somewhere. Human incentives to ship waste raise a concern for EJ in waste shipments. This paper focuses on this new perspective: whether a facility in a certain area receives more waste than other facilities in other areas.

[3] Ley et al. (2000) follows the approach of Nordhaus et al. (1973) to model the use over time of spatially differentiated resources. Ley et al. (2002) applies the model of Gaudet et al. (2001) to determine the solution for the intertemporal planning problem.

Specifically, considering all available disposal facilities within 60 miles' driving distance from the population center of the waste-generating county, do the demographic characteristics of the neighborhood surrounding the facility explain the haulers' choice of facility?

The analysis of the status quo correlation between race and waste flows in California in 2010 shows that, controlling for income, waste is more likely to be sent to facilities in communities with a high percentage of minorities than to facilities in white communities. The disparities for Hispanic communities and black communities persist once I control for disposal fees, and the disparity for Hispanic communities disappears once I control for disposal fees and distance. These results suggest facilities in Hispanic communities tend to be close to the population centers of waste origin. By contrast, facilities in black communities are attractive to haulers for reasons other than disposal fees and transport proximity, such as ownership types and access to railway. The list of reasons is not exhaustive, and other unobserved characteristics of the facility or of the facility neighborhoods matter in haulers' decisions for facilities in black communities.

Although showing the causes of environmental injustice is beyond the scope of this paper, I focus on the implications of NIMBY on the racial distribution of waste shipments. I emphasize the extent to which disposal fees and transport costs contribute to the disproportionate distribution of waste shipments by race and highlight that the NIMBY laws, by altering disposal fees or the availability of disposal options, may not reduce the current disproportionate distribution of waste. In fact, if import bans are implemented in all counties in California, waste that is sent to facilities near white residents would be rerouted to facilities near Hispanic residents, exacerbating the distributional concern. The reason is that facilities in Hispanic communities tend to be close to centers of waste-generating places. Meanwhile, waste that is sent to facilities in black communities would remain fairly constant, because these facilities offer haulers benefits beyond reasonable disposal fees and transport proximity. These results suggest NIMBY laws could have unintended consequences on the distribution of waste flows by race. Alternative instruments are needed to account for EJ issues as well. For example, if haulers prefer facilities in disadvantaged communities because these facilities do not follow environmental standards and accept all of haulers' waste, frequent inspections and strict enforcement of the standards may provide a better scope in waste management.

The rest of the paper is structured as follows. Section 1 provides background on transboundary waste shipments and NIMBY-motivated laws, as well as an overview of the EJ literature. Section 2 provides a general picture of data on waste disposal in California. Section 3 presents the model and the estimation results. Section 4 reports the impacts of counterfactual NIMBY laws on intercounty waste flows and the haulers' costs of discarding waste. Section 5 discusses the potential unintended consequences of NIMBY on EJ. Section 6 concludes with a summary and suggested extensions.

# 1 Background

## 1.1 The controversy over transboundary waste shipments

Historically, disposal of solid waste took place at local town dumps and was then transported to regional and large-scale facilities. In the 1990s, stricter government regulation to protect human health and the environment led to major changes in the scale and scope of waste-handling technologies.[4] Many landfills that did not meet the standards were forced to closed. The town dumps were replaced by state-of-the-art and large scale facilities.[5] The amount of solid waste transported across states and counties also increased dramatically. Between 1989 and 1999, interstate waste transport jumped by 300%, from 10 million tons to 30 million tons (Repa, 2005).

Several states became overwhelmed by the increasing waste imports and attempted to limit them. Many citizen groups, environmental organizations, and state legislators expressed concern about their regions being a dumping ground, the impact of landfill growth on local property values, the limited capacity of local landfills, and the interference with local recycling efforts (if waste was imported from places with poor handling standards). The opposition led to several ordinances that taxed out-of-state waste, restricted imports to waste of equivalent handling standards, or even banned the imports. However, the Supreme Court's decisions overturned these attempts on the basis that they discriminated against interstate commerce. The court found waste to be an "ordinary commodity" and restriction on interstate shipments of the ordinary commodity to be "protectionist" (*Philadelphia v. New Jersey*, 1978). The Supreme Court also made clear that under the "dormant" Commerce Clause of the Constitution, states may not erect barriers to interstate commerce unless Congress explicitly allows it.[6]

Hence, the legislative efforts to limit interstate waste transport have been put to a number of crafted bills in Congress. In every Congress since 1990, legislation aiming to authorize states to control interstate waste flows has been introduced but has not been successfully enacted.[7] In the

[4]The Congress sought a reform of solid waste management in subtitle D of the 1976 Resource Conservation and Resource Recovery Act (RCRA). The US EPA established final rules and implemented the practices from 1991 to 1997. These rules set criteria for location restrictions and standards for the design, operation, groundwater monitoring, financial assurance, closure and post-closure care for solid waste landfills.

[5]Kinnaman and Fullterton (1999) note that prior to the RCRA, almost every town in the US had a local dump. Macauley (2009) reports that the number of landfills in 1988 was nearly 8,000 but fell to 2,300 in 1998. Repa (2000) notes that while the number of public landfills decreased, the number of private landfills increased substantially, from 17% in 1984 to 36% in 1998.

[6]Some examples include a New Jersey statute that prohibited out-of-state waste imports in *Philadelphia v. New Jersey* (1978), an Alabama statute that imposed a fee on out-of-state hazardous waste in *Chemical Waste Management Inc., v. Guy Hunt, Governor of Alabama* (1992), an Oregon statute that imposed a surcharge on out-of-state solid waste in *Oregon Waste Systems Inc. v. Department of Environmental Quality of the State of Oregon* (1994), and a Wisconsin statute that required out-of-state communities to adopt Wisconsin recycling standards if exporting to Wisconsin facilities in *National Solid Waste Management Association v. Meyer* (1999).

[7]In 1994, both the House and Senate passed the "State and Local Government Interstate Waste Control Act"

115th Congress (2017-2018), a bill was introduced to both the Senate and the House under the name Trash Act. This bill aims to allow state and local governments to restrict out-of-state waste coming from states that have lower waste-handling standards than the receiving state and to charge a fee for out-of-state waste.

This paper studies the effects of NIMBY laws in terms of taxing or banning transboundary waste flows, using the example of intercounty waste transport in California. Despite limiting the scope to intercounty waste instead of interstate waste, studying intercounty waste provides insights on movements of transboundary waste flows. The case of intercounty waste in California is also interesting by itself. In 1984, Solano County in California enacted Measure E, which limited imported quantities. The measure was prevented from being enforced in 1992, due to the concern about violating the Commerce Clause. In 2009, opponents of the landfill expansion in Solano filed a lawsuit aimed at reinstating Measure E. In 2012, however, California passed a bill prohibiting local ordinances from restricting the importation of solid waste into local privately-owned disposal facilities based on place of origin.[8] The legislation on interstate waste restrictions by Congress may set a new precedent to bring back similar measures at the county level.

At the international level, note that international waste shipments are motivated by a very different trade-off and determinants. Whereas the intercounty and interstate waste can be explained by the variation in tipping fees that can justify the incurred transportation costs, the international waste shipments are mostly motivated by the differences in environmental standards across countries that can justify the costs of building new waste facilities at home or relocating entire production to a foreign country; see Ederington et al. (2005) and Kellenberg (2012).[9] Hence, studies on international waste are motivated by the pollution-haven literature that suggests environmental regulations affect production location (e.g., capital-intensive and "dirty" industries), trade, and foreign direct investment flows.

Besides issues on transboundary waste, a growing amount of recent research on solid waste has explored other topics of the industry. Petkus (2008) exploits the quasi-exogenous change in market

that prohibits a landfill or incinerator from receiving out-of-state solid waste unless it obtains authorization from the affected local government to receive such waste. However, the bill was not enacted, due to a lack of agreement on common language in the enactment. Another bill in a later session (S. 534 in 1995) that authorizes states to prohibit out-of-state solid waste and to reinforce local waste-flow control exercised before 1994 was passed in the Senate but retained in the House.

[8] South Carolina also prepared a similar Senate Bill 203 in 2013, but the bill still resides in the state Senate.

[9] Within a country, the differences in environmental standards among counties and states may be negligible. Transportation costs still matter: waste from New York has been exported to nearby states such as New Jersey, Pennsylvania, Maryland, West Virginia, and Virginia and has been challenged by these five states rather than other regions in the US. Private haulers, when challenged by the waste-flow restrictions, justify their intercounty and interstate shipments by the economic incentives, that is, variation in tipping fees. Hence, the transboundary waste shipments within the US have been protected by the Interstate Commerce Clause. Meanwhile, international waste shipments require certain bilateral agreements between two countries, which implies corrupt politicians and organized crime may also play a role in some cases of waste trade in a country; see Kellenberg (2015).

structure of the industry due to the 1993 enforcement of the RCRA regulation in Illinois to study the causal effect on prices among surviving landfills. Kamita (2001) considers the final disposal stage and analyzes the consequences of mergers between disposal facilities. Ho (2019) considers changes in neighborhood demographics in response to openings and closings of solid waste facilities to test the residential mobility hypothesis in the environmental justice literature. Salz (2022) focuses on the collection stage and studies the role of intermediaries between commercial establishments and private waste haulers in New York's trade waste collection market.

## 1.2 Environmental justice (EJ)

The EJ movement started from the illegal dumping of 31,000 gallons of PCB-contaminated oil along 240 miles of North Carolina highways. The state collected contaminated soil and identified a landfill site for the waste. The choice of Warren County site, which was predominantly low income and black, led to heated contention. Protests that followed motivated the first two influential studies by the U.S. General Accounting Office (1983) and the United Church of Christ's Commission on Racial Justice (1987) that showed poor and minority groups were unevenly exposed to hazardous waste sites in many parts of the US.

Since then, scholars have been gathering evidence for the uneven distribution of undesired environmental risks by demographics (race and income) and providing alternative explanations for the distribution. A recent review by Banzhaf et al. (2019) classifies possible mechanisms into four categories: disproportionate siting by firms, "coming to the nuisance" on the household side, market-like coordination between the two sides in a Coasean bargaining process, and discriminatory politics and enforcement. For example, Baden and Coursey (2002) and Mohai and Saha (2007) revisit racial disparities around hazardous waste treatment facilities using several methods to better control for proximity between hazardous sites and nearby residential populations. They find the disparities persist even when controlling for economic and sociopolitical factors, suggesting that factors uniquely associated with race, such as racial targeting, housing discrimination, and so on, are associated with the location of hazardous waste facilities. Wolverton (2009) models firm location as a decision variable and finds the disproportionate siting seems to arise from economic factors such as land cost, labor, and access to transportation, rather than directly from local demographics. Banzhaf and Walsh (2008), Gamper-Rabindran and Timmins (2011), and Ho (2019) consider changes in demographic composition over time and suggest environmental injustice is explained by nuisance-driven residential mobility. Timmins and Vissing (2017) look at the third category and examine the content of leases between shale gas operators and households in Tarrant County, Texas. They find race and speaking in English are correlated with lease terms and royalty compensation. Gray and Shadbegian (2004) and Shadbegian and Gray (2012) examine the demographic determinants of regulatory stringency in terms of penalties and inspection frequencies in communities near polluting facilities, and find mixed results.

This paper considers a new perspective on EJ in solid waste disposal. This new perspective stems from the distinct difference between solid waste and other nuisance matters. That is, waste can be legally transported from a place to another place. This legal movement generates two EJ issues in the solid waste industry. One is exposure to the presence of a facility. The other is exposure to waste shipments. Previous studies have focused on the first perspective by comparing demographic characteristics or amenities between an exposed neighborhood and far-away areas and/or between the period before and after the facility appearance, thereby providing alternative hypotheses—disproportionate siting by firms or residential mobility—as mentioned above. This paper studies the EJ perspective of waste shipments. I consider the variation in waste shipments that originate from a county but end up at different disposal facilities. These waste shipments arise as a result of haulers' optimization choices for disposal facilities, which may correlate with the racial composition of the surrounding neighborhoods, leading to unintended consequences of NIMBY laws.[10]

Addressing the EJ perspective of a regulation is important, because the US EPA has recently integrated EJ in its programs and policies. Following President Clinton's issuance of a 1994 executive order and federal actions to address EJ in minority populations and low-income populations, Plan EJ 2014 was issued to lay a foundation for integrating EJ in EPA activities. The EJ 2020 Action Agenda then provides strategic plans for advancing EJ. The economic literature on environmental policies has also addressed EJ implications of the policies. For example, Fowlie et al. (2012) examine whether cap-and-trade in California's NOx trading program leads to disproportionate distribution of emissions by neighborhood demographic characteristics of the facilities in the program. Also using the California context, I discuss the implications of NIMBY laws in municipal solid waste management.

Note that this paper shares some similarity with Fowlie et al. (2012), who study tradable permits and EJ. The common theme is the concern about the distribution of marketable bads in which environmental bads may be legally moved from one place to another. In this case, because (environmental) bads are marketable, they may be traded such that they end up at traditionally disadvantaged communities. Yet, Fowlie et al. (2012) and my paper differ in several ways in their context and study direction. In the emissions-permit context, Fowlie et al. (2012) find that emissions are disproportionately distributed in the absence of tradable permits and the marketable permits do not exacerbate the preexisting inequalities. In my context, I find waste disposal is unevenly distributed in the marketable environment, and the NIMBY motions that aim to interfere with market activities

[10]The paper does not consider exposure to shipments along the transport route, but rather exposure to shipments ending at facilities.

may exacerbate the inequalities.

## 2 Data: Solid waste disposal in California

To illustrate the effects of NIMBY on interjurisdictional waste flows, I use the data on intercounty waste in California, because not many states in the US report waste flows by place of origin and by disposal facility. The amount of out-of-state exports from California is also very modest, 1.16% during 1995–2015, which allows the focus on intercounty waste transport.

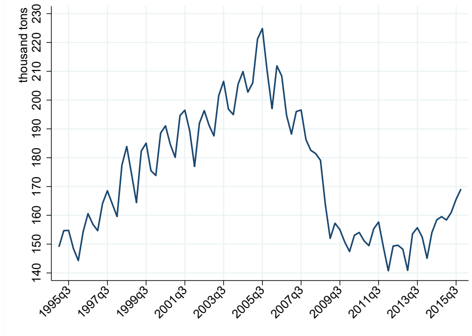
Data on intercounty waste flows are collected from California's Department of Resources Recycling and Recovery (CalRecycle). The data show trash quantity by county of origin and by facility of destination, quarterly from January 1995 to December 2015. This quantity dataset is then combined with the data on quarterly disposal price (tipping fees) from Waste Business Journal, an industry research and analysis company. In the waste industry, the tipping fee is known as the fee charged per ton to unload solid waste at a landfill or transfer station. For measurement of transport distance, I use HERE maps to measure the driving distance from a population-weighted centroid of a county to a facility location.[11] For more details about the data and how they were processed for the analysis, see online Appendix A.

The data show the trends in waste disposal in California mirror the national trends. Figure 1a shows the total waste amount generated by a county increased steadily in the 1990s and early 2000s but dropped dramatically from 2005. The drop may be correlated with the economic recession in 2008, but it may be mainly attributed to enormous recycling efforts and zero waste policies in California in the late 2000s. For example, in 2002, San Francisco set a goal of 75% diversion by 2010 and zero waste by 2020. The number of disposal facilities in fact has been decreasing since 1995; see Figure 1b. Mirroring the national trends in the 1990s due to the enforcement of the RCRA, a large number of disposal facilities were closed. California had more than 200 facilities in 1995 but only 170 in 1998.

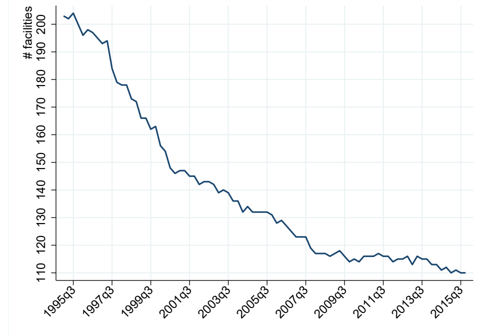
Figure 1c shows the average tipping fee (weighted by waste shipments) dropped from $38/ton in 1995 to $33/ton in 1997 but then escalated to $42/ton beginning in 2005. The short-run drop in the 1990s may be attributed to the expansion of many state-of-the-art landfills and new builds of a few but large-scale facilities after the RCRA. Gradually, the mass of disposed trash and opposition to the expansion of existing landfills and construction of new landfills may lower existing disposal capacity, resulting in the jump in disposal fees.

Therefore, the increase in long-haul shipments of trash is not surprising. Figure 1d shows that, along with the drop in the number of local disposal sites, the proportion of trash a county sends

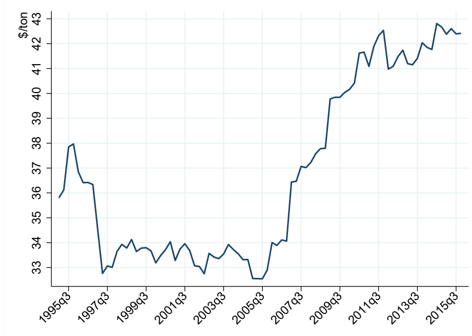
[11]HERE is a company working on digitizing mapping and in-car navigation systems, `https://www.here.com/company`.



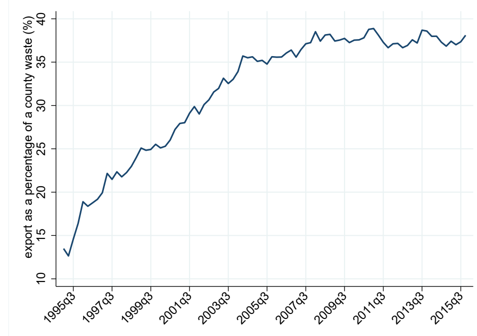

(A) Total generated waste per county



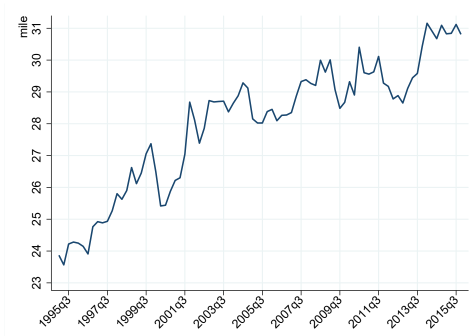

(B) Number of disposal facilities in California



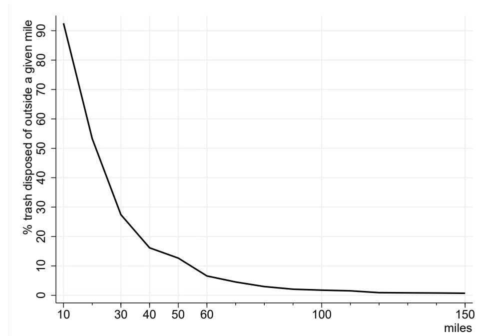

(C) Average disposal price ($/ton, in 2000 dollars) paid by haulers in a county




(D) Percentage of waste one county sends to other counties




(E) Average distance of waste shipments from a county to a disposal facility




(F) Percentage of waste transported beyond a given distance

FIGURE 1: Overview of solid waste disposal in California from Jan. 1995 to Dec. 2015

*Note:* The graph shows a general picture of waste flows in California from quarter 1, 1995, to quarter 4, 2015. Distance is driving distance from population-weighted coordinate of the waste-generating county to a disposal facility. Panel 1f shows the percentage of waste that is transported beyond a given distance.

to other counties for disposal climbed from 15% in 1995 to nearly 40% in 2015. This climb was accompanied by an increase in shipping distance. Waste is traveling farther and farther to reach a disposal site, from 24 miles in 1995 to 31 miles in 2015; see Figure 1e.

However, note the shipping distance is still in a reasonable economic range. My conversations with waste-collection companies as well as with a representative in the National Waste & Recycling Association, a trade association for the private waste management sector, reveal that trucks generally cart waste to a disposal facility that is less than about 30–45 miles from the place of collection. Figure 1f plots the percentage of waste transported beyond a given distance. It shows less and less trash is shipped to a facility as the transport distance increases. The amount of trash carted plummets quickly for distances ranging from 30 to 60 miles, followed by a flat tail for distances beyond 60 miles (up until 700.17 miles, according to the 1995–2015 data).

In the next section, I recover the haulers' preferences over disposal price and transport distance when they decide on the facilities where they will deposit waste. Hence, I need to define a choice set of facilities that a hauler considers as alternative options when making a decision. Given more than 90% of waste (93.42%) is disposed of within 60 miles, defining the choice set that includes all facilities within 60 miles of the population centroid of the county of waste origin is reasonable. Figure B1 in online Appendix B plots the price response and distance response by distance travel knot using the samples of waste flows (including zero shipments) within 120 and 150 miles. Results show significantly negative effects of price and distance on trash flows in the first few knots of distance (from 0 to 90 miles). The effects dwindle in distance. Beyond 80–90 miles, trash flows no longer respond to price and distance, suggesting a certain distance limit exists within which trash flows economically respond to price and distance. If waste is transported farther than that limit, a reporting error or a designation beyond the economic reasons is the explanation.

Given that most of waste in California (93.42%) is disposed of within 60 miles of the population centroid of a county of waste origin and the price and distance responses diminish in distance, I use 60 miles as a market radius to define choice sets. Yet, ignoring waste beyond 60 miles would be a strict assumption. I consider disposing of waste beyond 60 miles an outside option with a normalized utility.

Table 1 shows summary statistics of the main sample, that is, all combinations of flows within 60 miles. Panel A contrasts the waste-flow characteristics of the sample with the raw data of positive flows (without being restricted to 60 miles). The unit of observation is quarter $\times$ waste-origin county $\times$ waste-destination facility. Contrasting waste shipments, distance, tipping fee, total trash generated in a county, and out-of-county exports, the sample of waste flows within 60 miles remains typical features of the picture of waste disposals of all of California. On average, a county sends 21,000 tons of waste to a facility. The average distance is 24 miles and the average price is \$36/ton. Panel B shows the characteristics of the choice set of 60-mile options. The unit of observation is quarter $\times$ origin county. Compared with the unrestricted sample, the sample of 60-mile waste flows has fewer observations because in certain quarters, a few counties sent their waste only to facilities beyond 60 miles. The average market size (average trash amount a county

TABLE 1: Summary statistics of panels of waste flows

| | count | mean | sd | min | max |
|---|---|---|---|---|---|
| *Panel A: Flows characteristics (unit: quarter × origin county × destination facility)* | | | | | |
| *A1: Flows within 60 miles of the population-weighted centroid of a county* | | | | | |
| quantity (ton) | 36,186 | 21,453.27 | 70,161.38 | 0 | 1,063,515 |
| distance (mile) | 36,186 | 37.12 | 14.91 | 1.73 | 59.93 |
| waste-weighted distance (mile) | 36,186 | 23.52 | 12.90 | 1.73 | 59.93 |
| waste-weighted price ($/ton) | 36,186 | 36.40 | 12.10 | 1.50 | 181.00 |
| *A2: All positive flows in California, including shipments beyond 60 miles* | | | | | |
| quantity (ton) | 53,957 | 15,401.27 | 58,388.94 | .01 | 1,063,515 |
| waste-weighted distance (mile) | 53,957 | 28.00 | 23.23 | 1.73 | 700.17 |
| waste-weighted price ($/ton) | 53,957 | 36.49 | 12.18 | 1.50 | 181.00 |
| *Panel B: Choice-set characteristics (unit: quarter × origin county)* | | | | | |
| *B1: Within 60 miles* | | | | | |
| total disposal per county (ton) | 4,431 | 175,199.3 | 416,191 | 1.6 | 3,573,185 |
| out-of-county exports (%) | 4,431 | 21.68 | 33.34 | 0 | 100 |
| number of options | 4,431 | 8.17 | 5.24 | 1 | 30 |
| *B2: All choices in California* | | | | | |
| total disposal per county (ton) | 4,788 | 173,560.3 | 426,099.1 | .37 | 3,881,458 |
| out-of-county exports (%) | 4,788 | 31.62 | 38.05 | 0 | 100 |

*Note:* Panel A shows summary statistics of the sample of trash flows; the unit of observation is quarter × origin county × destination facility. Panel A1 includes all waste-flow pairs between an origin county and a destination facility in a quarter (36,186 observations) within 60 miles, of which we have 24,473 observations of positive waste flows. Panel A2 includes only positive waste flows, but it covers all flows in California. Panel B1 shows summary characteristics of key indicators from the perspective of haulers in a market: total waste generated by a county (market size), the percentage of waste in the county that is exported to other counties (out-of-county exports), and the number of disposal facilities within 60 miles of the population-weighted centroid of the county (the number of options). Panel B2 is similar to Panel B1 but covers all choices in California (including choices observed in waste flows beyond 60 miles).

generates) is about 175,000 tons. A county exports about 22% of its trash to other counties in the main sample. Haulers in a market have an average of eight options for disposing of their collected waste.

# 3 Modeling waste flows

As Ley et al. (2002) and Macauley (2009) notice, the central economic factors behind waste shipments are the variation in tipping fees haulers pay disposal facilities and the transportation costs. Transboundary waste shipments are incurred because low disposal fees in distant facilities can justify the transportation costs to get to the facilities. This justification is due to the substantial variation in tipping fees that may be resulted from changes in the industry structure in the past. For example, Ley et al. (2002) note that the trend in interstate waste transport from the Northeast to the Midwest that developed during the 1990s was due to the closures of many landfills in New York and New Jersey and the inability of northeastern states to open new landfills. This change in the industry structure caused a sharp increase in the tipping fees at the remaining landfills in the Northeast. Whereas the fees in northeastern states are typically more than \$50/ton, the fees in midwestern states were only about \$25–\$30/ton. Thus, even with the transportation costs, exporting waste to the Midwest can remain cheaper.

To focus on the central trade-off between disposal fees and transportation costs, I model the location of waste shipments as haulers' demand for waste disposal facilities. Specifically, given a set of alternative dumping sites, a hauler chooses a disposal facility to minimize the costs of discarding the waste collected from households. The discarding costs include tipping fees, transportation costs, and other implicit costs associated with specific facilities.[12] This demand model is useful to predict counterfactual waste shipments if a NIMBY enactment changes the relative trade-off between tipping fees and the transportation costs (e.g., import taxes), or the available alternative dumping options (e.g., import bans).

In the short run, facilities may not adjust tipping fees in response to a NIMBY enactment. In the medium run, facilities may adjust their tipping fees. I hence include a supply side in which facilities set their disposal prices to maximize total operating profits given the potential waste received. I do not consider the long run, in which entries and exits are endogenous choices of facilities.

## 3.1 The model

**Demand: Haulers choose facilities to deposit waste to minimize discarding costs**

To model the demand for waste disposal, I use a logit discrete-choice framework. A hauler $i$, after collecting waste from households in county $m$ in quarter $t$, chooses facility $j$ to dispose of the collected waste. The choice of facility $j$ aims to minimize the following discarding cost:

$$C_{ijmt} \equiv \beta X_{jmt} + \epsilon_{ijmt} = \beta_p \, \textit{price}_{jt} + \beta_d \, \textit{distance}_{mj} + \beta_l \, \textit{local}_{mj} + \gamma_j + \delta_t + \epsilon_{ijmt},$$

where $\textit{price}_{jt}$ is the tipping fee at facility $j$ in quarter $t$, $\textit{distance}_{mj}$ is the driving distance between the population-weighted centroid of a waste-generating county and the facility location, and

[12] Whereas discarding literally means disposing of, the term "discarding cost" in this paper refers to total costs a hauler incurs to get rid of the waste it collects from households, not just the disposal price. Disposal price refers to tipping fees (the price paid by the hauler to the disposal facility).

*local*$_{mj}$ is an indicator for the choice of local disposal option (disposing of waste at a facility inside the county of waste origin). $\gamma_j$ are facility fixed effects, $\delta_t$ are time fixed effects, and $\epsilon_{ijmt}$ is a cost shock that is i.i.d. across haulers. I normalize the mean cost of the outside option to zero.

Assuming $\epsilon_{ijmt}$ follows type I extreme-value distribution, the probability that the facility $j$ of available options in the choice set $\mathbb{M}_{mt}$ is chosen by hauler $i$ is

$$P_{ijmt} = \frac{\exp(\beta X_{jmt})}{\sum_{k \in \mathbb{M}_{mt}} 1 + \exp(\beta X_{kmt})}.$$

Several notices are marked. First, haulers $i$ are hypothetical agents, because I do not observe data at the hauler level. I instead observe the data at the market level, the waste amount from county $m$ to facility $j$. Hence, the hauler in this model includes several cases. It can be a private hauler, a waste service firm that owns both the landfill and the collection service, or the municipality that later contracts with the private landfill's owner or owns the landfill.[13] In all cases, the justification between transport costs and disposal fees at the gates of disposal facilities is the centerpiece of the total costs of carting waste for disposal and is the one I focus on.

Second, controlling for time fixed effects $\delta_t$ and facility fixed effects $\gamma_j$ is important. The time fixed effects aim to adjust seasonal effects and systematic shocks of the industry and the economy over quarters and years. The facility fixed effects aim to control for time-invariant characteristics of facilities during 1995–2015 that affect the hauler's costs of discarding waste and the hauler's choice of a disposal facility. Broadly speaking, these characteristics may affect prices, causing the price coefficient to be biased if the fixed effects are not included. For example, the hauler may prefer a facility with flexible operation hours or on easily accessible highways. These factors may add to the operation costs and the disposal price. Hence, omitting these characteristics will cause the price coefficient to be biased towards zero. Assuming these characteristics do not changed significantly over the period 1995–2015 (relatively between facilities), facility fixed effects can capture them to some extent and mitigate the upward bias of the price coefficient.

However, including facility fixed effects does not mitigate the potential upward bias, due to vertical integration and measurement error in price.[14] Specifically, a hauler may be vertically

[13] Activities in the collection stage of solid waste result from both exclusive contracts between a local government and a hauler, and nonexclusive services between market participants. Waste generated by residential customers is often collected either by local governments or by private haulers pursuant to contracts bid on, or franchises granted, by municipalities. These contracts and franchise agreements grant exclusive rights for the hauler to collect waste in a defined residential area. However, private waste haulers can contract directly with businesses and multi-family establishments for the collection of waste generated by commercial accounts.

[14] The municipal solid waste industry has several cases of vertical integration but maintains certain degree of competition. In responding to stricter regulations on operation standards in the 1990s (the RCRA), some private firms, such as Waste Management Inc. and Republic Services Inc., found vertical integration is a means to consolidate economy of scale and ensure large volumes of waste could be taken to large-scale facilities. As McCarthy (2004) notices, consolidated firms often ship waste to their own disposal facility across a border, rather than to an in-state facility owned

integrated with a disposal facility as one waste management firm. This vertical integration allows the firm to exploit economies of scope and operate at total lower costs of waste collection and waste disposal. Hence, the hauler associated with the firm will implicitly face a lower price than other non-integrated haulers. One possible way to mitigate the bias is to include the indicator dummy for the vertical-integration relation between a hauler and a disposal facility. Unfortunately, the data at the individual hauler level or at least the hauler entity are not available. To deal with this omitted-variable bias, I use an IV strategy that exploits exogenous variation in total waste quantity generated by counties; see Section 3.3. This IV strategy also mitigates the bias caused by measurement error in prices, due to the fact that I observe spot prices rather than actual transacted prices.

The third feature of the logit discrete-choice demand is that the ratio $\beta_d/\beta_p$ captures the hauler's willingness to pay to transport waste. This estimate of the transportation costs includes the costs incurred due to different travel distances to different facilities. The costs include fuel costs, labor costs (due to hours of driving), and maintenance and depreciation costs (due to hours of operating).

With this demand model, one can explore the counterfactual disposal locations (and thus waste shipments) under counterfactual NIMBY laws imposed on haulers, such as import taxes and import bans, assuming the facilities do not change their prices in the short run. For example, an import tax will add extra fees in the variable $price_{jt}$ for facilities outside the county of waste origin.[15] An import ban will change the choice set $\mathbb{M}_{mt}$ a hauler in county $m$ faces. The probability a facility being chosen in that case would depend on the relative price and distance between facilities within a county in which price and distance remain the same as before the policy. Hence, using the demand model alone to examine the effects of NIMBY laws helps us understand how the key substitution patterns between local dumping options and out-of-county options explain the effects of NIMBY, all else being equal.

Whereas studying the effects of NIMBY laws using the demand side alone gives us a transparent mechanism of the effects, adding a supply side to consider how facilities adjust tipping fees to respond to policies provides more realistic medium-term results.

**Supply: Facilities set tipping fees**

I use a standard oligopoly model of competition in which facilities set prices to maximize their operating profits. I take as given the industry structure and the location of facilities. Formally, let a

by a rival. However, Kamita (2001) suggests the disposal market has room for competition. In fact, many merger and acquisitions cases have been challenged by the US Department of Justice. I discuss the potential issue caused by vertical integration and the industry structure in California in more detail in Section 3.6.

[15] One can also study the effects of a trash tax or a vehicle-miles-traveled tax imposed on haulers, by considering additional terms on $price_{jt}$ for all facilities or on the willingness to pay for transportation. However, I do not consider in this paper, which focuses on NIMBY enactments.

facility $j$ serve a subset $\mathbb{F}_j$ of counties in California. The subset includes all counties of which the population centroid is within 60 miles of the facility location. The facility sets a uniform spot price $\mathit{price}_j$ to maximize the operating profits conditional on the tipping fees set by the other facilities at a time $t$. The profit function of facility $j$ is

$$\pi_j = \sum_{m \in \mathbb{F}_j} \mathit{price}_j \cdot P_{jm} \cdot Q_m - \mathcal{C}_j \left( \sum_{m \in \mathbb{F}_j} P_{jm} \cdot Q_m \right),$$

where $Q_m$ is total waste generated by county $m$ and $\mathcal{C}_j(\cdot)$ is a nonlinear cost function of facility $j$, which depends on the total waste the facility receives from all counties it serves.

Assuming the existence of pure-strategy Bertrand-Nash equilibrium in prices, the profit-maximizing price $\mathit{price}_j$ satisfies the following first-order condition:

$$\mathit{price}_j - \mathcal{C}_j' \left( \sum_{m \in \mathbb{F}_j} P_{jm} \cdot Q_m \right) = - \frac{\sum_{m \in \mathbb{F}_j} P_{jm} \cdot Q_m}{\sum_{m \in \mathbb{F}_j} \frac{\partial P_{jm}}{\partial \mathit{price}_j} \cdot Q_m}.$$

The noticeable feature of the cost estimation in this paper is the nonlinear marginal cost. I estimate the marginal cost $\mathcal{C}'$ as a quadratic function of total waste received. This estimation of a nonlinear cost is important for two reasons. First, the nonlinear marginal-cost function represents the incorporation of nonlinear production factors. Ideally, one would incorporate the capacity constraints into the cost function as in the cement industry; see Ryan (2012). The idea is to illustrate that production near capacity creates shadow costs, and the marginal cost would increase in production once utilization exceeds capacity. Because of the unavailability of capacity data, I smooth the nonlinear cost function and estimate it as a quadratic function. If the quadratic marginal cost has a positive quadratic coefficient, it illustrates the increasing marginal-cost feature once total waste received exceeds a threshold (the minimum-marginal-cost output).

Second, the nonlinear marginal-cost function allows us to capture that a disposal facility has economies of scale or diseconomies of scale (in marginal costs), that is, that facilities have decreasing or increasing marginal costs. This is consistent with the assumption on costs that will allow us to exploit the variation in the total waste amount a county generates to create an IV for prices in the demand estimation; see Section 3.3. In fact, I later show that the reduced-form estimation that looks at the relation between price and total potential waste received (as an IV) confirms the existence of economies of scale and hence the nonlinear relation between marginal cost and total waste received.

## 3.2 Estimation

Note that I do not observe the disposal-facility choice at the hauler level. Instead, I observe the waste amount by county of origin and facility of destination, that is, market-level data. Estimation of multinomial logit discrete-choice models with the market-level data has been well documented in Berry (1994); Berry et al. (1995). The contraction-mapping result in Berry (1994) shows a unique mean utility vector exists that matches the model-implied choice probability to observed market shares. Hence, given observed shares, we can solve for the choice probabilities and estimate preference parameters. However, this result only applies to the case of positive market shares. In my model, market shares may be zero because a feasible facility in the choice set may never be chosen by any haulers in the county in a quarter. An estimator that ignores these zero shares would be biased. To deal with this situation, I use the following maximum likelihood estimation, which is similar to the work by Martin (2008) (cited in chapter 13 in Train, 2009).[16] The limitation is that it does not measure individual heterogeneity in the choice probability of hauler/trip $i$ within a market.

To obtain the model likelihood, start with the probability that hauler $i$ chooses the facility $j$ that he was actually observed choosing:

$$f(Y_{imt}; \beta) = \prod_{j=1}^{J} P_{ijmt}^{y_{ijmt}},$$

where $y_{ijmt} = 1$ if hauler $i$ chose $j$, and 0 otherwise (in market $ct$). The log-likelihood function of the model is

$$L(\beta) = \sum_{c,t} \sum_{i} \sum_{j} y_{ijmt} \log P_{jmt}$$
$$\Leftrightarrow L(\beta) = \sum_{c,t} \sum_{j} \log P_{jmt} \sum_{i} y_{ijmt}.$$

Assume picked-up waste amounts within a market at a given time have the same size, namely, $q_{imt} = q_{mt}$; then, the market share of a county's waste that is dumped at facility $j$ is

$$s_{jmt} \equiv \frac{\sum_i q_{imt} y_{ijmt}}{Q_{mt}} = \frac{q_{mt} \sum_i y_{ijmt}}{Q_{mt}},$$

where $Q_{mt}$ is the total waste generated by households in county $m$ at time $t$. Then, the log-

[16]Martin (2008) studies consumers' choice between incandescent and compact fluorescent light bulbs, where advertising and promotions occurred weekly and varied over stores, but stores did not sell any fluorescent light bulbs in a given week.

likelihood becomes

$$L(\beta) = \sum_{c,t} \sum_{j} \log P_{jmt} \cdot s_{jmt} \cdot \underbrace{Q_{mt}/q_{mt}}_{N_{mt}}.$$

Note that $Q_{mt}/q_{mt}$ is the number of haulers $N_{mt}$ in a market $m$ at a time $t$. Now, two maximum likelihood estimators exist, depending on the assumptions we believe.

The first estimator assumes the number of haulers across different markets is the same, namely, $N_{mt} = N \; \forall c, t$, which implies that market sizes differ because the picked-up waste amounts vary across markets. The log-likelihood function is

$$L(\beta) = \frac{1}{N} \sum_{c,t} \sum_{j} \log P_{jmt} \cdot s_{jmt}.$$

The second estimator assumes the picked-up waste amounts across different markets have the same size, namely, $q_{mt} = q \; \forall c, t$, which means all trash-collection trucks in California are the same size. The log-likelihood function becomes

$$L(\beta) = \frac{1}{q} \sum_{c,t} \sum_{j} \log P_{jmt} \cdot s_{jmt} \cdot Q_{mt}.$$

The second estimator implies that market sizes differ across markets because the number of collection trips and the number of haulers varies across markets. Given that this situation is more plausible, we use the second estimator for the main results.

With the estimates of the choice probability, I can recover the markup and the estimates of the marginal-cost function.

## 3.3 Identification

The distance coefficient is identified based on how waste flows vary by distance between the population center of a county and a disposal facility. The distance explains both the variation in the share of trash from different counties going to a facility and the variation in the share of trash from the same county going to different facilities.

The variation in trash shares going to different facilities within a county is also explained by disposal prices and other factors. The panel data allow me to exploit cross-sectional and time-series variation to control for facility fixed effects. Including facility fixed effects helps me identify the price coefficient and control for other factors that explain the choice of a facility. Without facility fixed effects, estimates for the price coefficient are upward biased, because price is endogenous in which price positively correlates with omitted variables that positively affect the likelihood of choosing a disposal facility. For example, haulers that face the costs of diverting materials for different types of waste will prefer facilities that do not strictly examine the incoming trash and do not turn away their trucks. Haulers will also prefer facilities with flexible operation hours or those on easily accessible highways. Those factors likely contribute to the operation costs of facilities and add up to high disposal prices.

In addition to reducing upward bias in estimating the price parameter, facility fixed effects explain variation in trash shares beyond the explanation from transport costs and disposal prices. For example, fixed effects also aim to capture the factors that are correlated with the demographics of a community near a facility, because Section 5 shows these demographic characteristics do affect the trash share going to a facility.

Nevertheless, facility fixed effects do not capture the relation between a specific hauler and a certain facility, such as vertical integration. Without observing the relation of vertical integration between a hauler and a facility to control for it, the estimate for the trade-off between disposal prices and transport distance would be underestimated, causing upward bias in the price coefficient. Another difficulty in getting a consistent estimate for the price coefficient is overcoming bias due to measurement error. The reason is that I observe listed prices rather than deviations from the prices that haulers may pay if they sign contracts with individual disposal facilities. To overcome both endogeneity and measurement error, I instrument for the price that a hauler coming from a given county would pay a facility with the quantity of waste generated by other counties that consider this facility an option for waste disposal. Specifically, the instrument is the sum of the market sizes of other markets that also consider the facility in their choice sets.

This instrument construction adds to the literature on industrial organization that has used direct cost shifters, BLP instruments (Berry et al., 1995), and Hausman instruments (Hausman (1996) and Nevo (2001)). Cost shifters such as prices of inputs that shift the supply but not the demand are rarely observed. Berry et al. (1995) use measures of isolation in characteristic space other than prices, such as own characteristics, the sum of characteristics of other own-firm products, or the sum of characteristics of competitors' products. However, these instruments vary little over time. Hausman (1996) and Nevo (2001) suggest own-firm prices in different cities within a region are valid instruments, due to common regional marginal-cost shocks. Similar instruments that can be developed in my context are prices of (indirect) competitors that compete with the facility in markets other than the instrumented market. However, this instrument may suffer measurement error if prices have measurement error.

The market-size instrument in this paper is compelling because it is correlated with price, even though deviations may exist between observed listed prices and actual contracted prices. The reason is the instrument exploits the variation in the total waste amount generated by households and the potential existence of nonlinear costs or economies of scale or diseconomies of scale of disposal facilities. For example, suppose the landfill currently has an economy of scale, that is, its marginal costs is decreasing in the amount of waste received. This scenario creates an opportunity for the landfill to charge lower tipping fees to attract extra waste from haulers without lowering the markup. So, if a hauler is in a county that is near other counties that generates a lot of waste, it will likely face lower prices at a disposal facility that serves all these counties. The first-stage regression below will test the relation between tipping fees and the IV, as well as the existence of an economy of scale or a diseconomy of scale.

Another condition for the variation in the IV to identify the price coefficient is that the instrument must be exogenous to the hauler's choice of the facility in the instrumented market. By construction, the instrument takes account of the size of other markets while excluding the size of the instrumented market. Hence, the instrument excludes the demand factors of the instrumented market. One may be concerned that the size of other markets may be correlated with the waste amount generated in the instrumented market, due to common geographical shocks such as the growth of the region's economy. However, note the hauler's cost-minimizing decision considers the choice of disposal facilities and explains the variation in market shares rather than market sizes.

For the implementation of the nonlinear logit demand model with an IV, I apply the control-function approach. Following the literature, the control function is estimated using the polynomial of residuals obtained from the first stage in which price is regressed on exogenous variables and instruments. In the main model, the polynomial terms enter as extra explanatory variables; see Petrin and Train (2010). I estimate models with the linear polynomial and quadratic polynomial of control terms.

## 3.4 Estimation results

Table 2 reports the results of the model. Columns (1), (2), and (3) report the estimates of specifications with fixed effects alone, fixed effects and the linear control function, and fixed effects and the quadratic control function, respectively. As expected, facility fixed effects alone do not resolve all bias in the price-coefficient estimate. Although the model's estimate of the price coefficient has the correct sign, it is extremely small and statistically insignificant. The resulting price elasticity is $-0.07$. Using the market sizes of the other relevant markets to instrument for price, the upward bias is significantly mitigated. The magnitude of the price coefficient becomes nearly two orders of magnitude bigger; price elasticity is $-4.93$. The positive sign of the first coefficient of the control function confirms the upward bias is corrected.

The first-stage result confirms the market-size IV is strongly correlated with disposal prices. The negative sign of the correlation reveals the industry is exhibiting economy of scale: haulers tend to be charged a low disposal price at a facility that is surrounded by counties that generate

TABLE 2: Results of the structural model

| Model | (1)<br>Facility<br>fixed effects | (2)<br>IV<br>linear control function | (3)<br>IV<br>quadratic control function |
|---|---|---|---|
| price | −0.003 | −0.163 | −0.198 |
| | (0.001) | (0.043) | (0.044) |
| distance | −0.033 | −0.034 | −0.034 |
| | (0.002) | (0.002) | (0.002) |
| local | 2.480 | 2.419 | 2.406 |
| | (0.042) | (0.057) | (0.058) |
| control term | | 0.161 | 0.1961 |
| | | (0.043) | (0.044) |
| control term$^2$ | | · | −45.059e−6 |
| | | | (43.627e−6) |
| linear-cost term | | −39.078 | −60.598 |
| | | (63.506) | (26.270) |
| quadratic-cost term | | 2.754 | 4.466 |
| | | (1.893) | (2.124) |
| First stage results: | | price | |
| total market sizes | | −0.107 | |
| (100,000 tons) | | (0.059) | |
| **1**(serve at least 2 markets) | | 44.755 | |
| | | (1.112) | |
| distance | | −0.006 | |
| | | (0.002) | |
| local | | −0.382 | |
| | | (0.084) | |
| 1st stage adjusted $R^2$ | | 0.696 | |
| F test | | 1080.95 | |
| price elasticity | −0.073 | −4.059 | −4.934 |
| distance elasticity | −0.579 | −0.597 | −0.600 |
| markup | −1.080 | 0.266 | 0.318 |

*Note:* Specification (1) is the facility fixed-effects model. Specifications (2) and (3) use the sum of other relevant market sizes as an IV and the control-function approach with linear and quadratic forms, respectively: the price value of observation $mjt$ is instrumented by the sum of the market sizes of other relevant markets (excluding the size of the instrumented market). A market is relevant if its choice set contains facility $j$. Standard errors are bootstrapped. Price elasticities are the average over all observations. All specifications include facility and time fixed effects.

a lot of trash. The estimates of the coefficients on the quadratic cost function also confirm the marginal cost is nonlinear. When the facility receives more waste than its minimum-cost output, it will move to the diseconomy-of-scale area in which the marginal cost will increase in the waste amount.

The distance coefficient is robustly estimated in all specifications. The coefficient is negative and statistically significant, implying a distance elasticity of $-0.60$.

The ratio between the distance coefficient and the price coefficient captures the hauler's willingness to pay for proximity to the disposal facility. The estimates imply the transportation cost is 17.17 cents/ton-mile (in 2000 dollars). This agrees with estimates from several publications. Also using the logit discrete-choice demand model, Kamita (2001) estimates the transportation cost in Illinois is 11 cents/ton-mile. Table 3.21 of the US National Transportation Statistics (US Department of Transportation, 2021) reports that revenues per ton-mile for general freight common carriers by truck in year 2000 was 11.32 cents/ton-mile and ranged from 5.47 to 20.20 cents over 1985–2018. Ley et al. (2002) telephoned experts in waste hauling and cite a consensus estimate of 11 cents/ton-mile. Fischer et al. (1993) estimate waste transportation in 1990 and 1992 cost from 16-36 cents/ton-mile.

## 3.5 Fitness

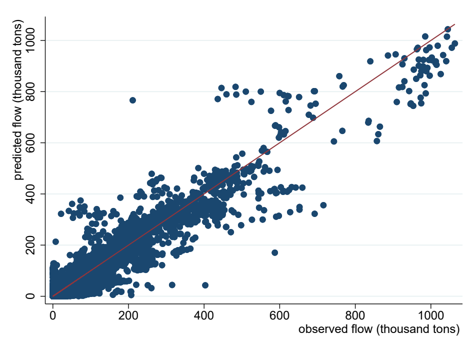
Figure 2 shows the scatter plots and correlation coefficients between observed values and fitted values of key variables. The key variables I consider are waste flows, waste-weighted average distance, and waste-weighted average price, because matching waste movements well to study the spatial and demographic distribution of waste flows is important. I also consider the goodness of fit in year 2010, because my analysis focuses on the demographic distribution in 2010. Overall, the model successfully replicates the waste flows, waste-weighted average distance, and waste-weighted average price, especially in 2010.

## 3.6 Tests and caveats

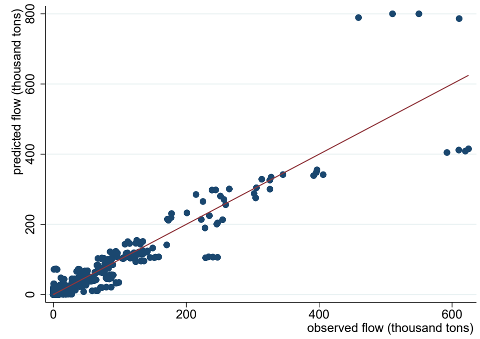
### 3.6.1 Measurement error of distance

Note that the distance variable is measured from the population centroid rather than other points in a county such as the geographical centroid. This measurement helps reduce the estimate bias due to measurement error, because the amount of waste generated is highly correlated with population. When a county has multiple waste collection points, the shipment from the places with more waste should be weighted more than shipments from other collection points.

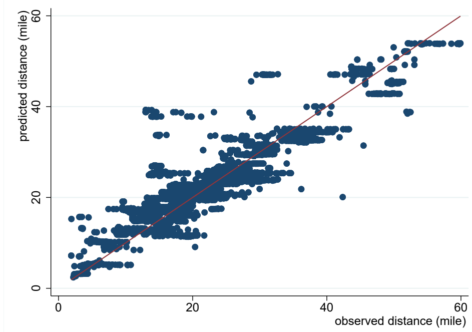
Yet, the measurement error may still be a problem if a county has multiple centers of similarly dense areas that are far away from each other. To check the robustness of the estimate of distance coefficient, I test whether the estimate holds up when county fixed effects are added. The reason is that if measurement error exists, the error will be significant for shipments from a very large county. For shipments in a small county, because the population centroid is not very far from other places, the difference between the distance from a population centroid to a given facility and the true distance from the waste-collection point to the facility is small. Hence, the estimate of the distance coefficient would be more reliable if the county fixed effects are added. Online Appendix



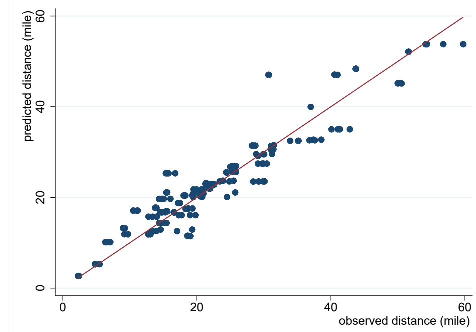

(A) Correlation in trash flows (= 0.957)



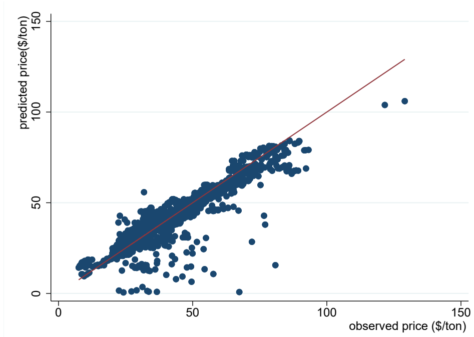

(B) Correlation in trash flows in 2010 (= 0.942)



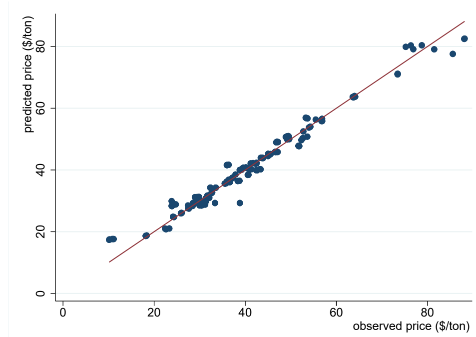

(C) Correlation in distance (= 0.935)




(D) Correlation in distance in 2010 (= 0.950)




(E) Correlation in price (= 0.944)




(F) Correlation in price in 2010 (= 0.988)

FIGURE 2: Model fit

*Note:* The graph shows the correlation coefficient between observed values and fitted values for several key variables. Panels 2a and 2b show the correlation in trash flows (trash amount generated from a county to a facility in a quarter); panel 2b shows the correlation in trash flows in year 2010. Panels 2c and 2d show the correlation in the (waste-weighted) average distance shipped by a county in a quarter. Panels 2e and 2f show the correlation in the (waste-weighted) average tipping fee by a county in a quarter.

C.1 shows the estimate is similar with and without county fixed effects, suggesting the estimate is robust and the measurement error of the distance variable is negligible.

### 3.6.2 Industry consolidation due to exits

As Figure 1 shows, the number of facilities fell by 50% between 1995 and 2015, significantly affecting the set of available choices for haulers. Although I do not model exits (and entries), the static demand-supply model in this paper emphasizes the effect of differentiated prices on waste flows, and hence captures the impacts of historical exits (via their impacts on prices) on waste flows.

As Ley et al. (2002) note, the consolidation of the industry due to exits caused a sharp increase in prices at landfills in the Northeast, motivating the transboundary waste shipments from the Northeast to the Midwest. Petkus (2008) studies and confirms the effects of exits due to the enactment of the Subtitle D of the RCRA 1991 on prices in Illinois. Hence, the change in the number of facilities in the solid waste industry is reflected in the change in prices. Because the demand model in this paper characterizes the characteristic space (price and distance) of a facility (product) rather than the product space, the model captures the effects of the (historical) industry consolidation on the choice of disposal facility (and hence waste flows).

What the model does not do is separating the direct effects of prices on waste flows from the indirect effects via change in exits on waste flows. Furthermore, because the primitives behind an exit decision are not estimated, the model cannot predict whether any consolidation is caused by the counterfactual NIMBY laws. In this respect, one can think of the counterfactual results predicted by this model as the ex-ante effects of NIMBY laws on waste flows in the short and medium run during which facilities make neither entry nor exit decisions. As the US Environmental Protection Agency (2016) notes, the pre-operational period including site surveys, permit application, and construction takes about 10 years, and the closure process requires extensive installation of final covers and caps that can cost between \$80,000 and \$500,000 per acre. Closures also require post-closure care that takes 30 years. Hence, in contrast to other industries, entry and exit of a landfill are very costly and take considerable time.

Given the central focus of the paper is on the effect of price on the choice of disposal location, one might be concerned whether the selection of exits would generate any bias on the estimation. As a check, I re-estimate the model using subsamples by period. Specifically, I use sample periods of 15 years and 9 years for the 1990s and 2010s, respectively. The reason for this division is the number of facilities fell dramatically between 1995 and 2007 but remained stable between 2007 and 2015; recall Figure 1. Results in Table C2 in online Appendix C suggest that the numerous exits in the 1990s and early 2000s potentially generated upward bias for the price coefficient. However, an estimator using large samples over a substantially long period (more than 15 years) helps mitigate the bias, because the fixed effects can be identified in large samples.

### 3.6.3 Industry structure

The solid waste industry has some firms that integrate the collection business with the landfilling operation. These firms typically own numerous landfills throughout the US. The US Environmental Protection Agency (2016) reports that the top five waste management companies in the US in 2015 by revenue are Waste Management (WM, \$12.96B), Republic Services (REPUB, \$9.12B), Clean Harbors (CLH, \$3.28B), Waste Connections (WCNX, \$2.12B), and Progressive Waste Solutions (PROG, \$1.93B). WM and REPUB together accounted for about 37% of the US waste revenue share and own 244 and 193 active landfills, respectively. CLH, WCNX, and PROG together own 12% of US waste revenue and 2, 44, and 23 landfills, respectively.[17] I call these firms superfirms.

With the vertical integration and operation of multiple landfills, these firms may have economies of scope and economies of scale to operate at lower costs and keep tipping fees relatively low. Not only are they able to offer relatively low tipping fees, but they would also have incentives to do that instead of raising prices to raise markups. The reason is they may need to keep a high volume of incoming waste to offset the high costs of constructing and maintaining large-scale landfills and large-scale operation. In such cases, the integrated haulers would transport waste to the integrated landfills regardless of high transport costs and alternative low-fee facilities near the waste-collection places. The superfirms may also offer some non-integrated haulers deep discounts on tipping fees to do the same. Without observing the vertical relation between a hauler and a facility and actual transacted tipping fees, estimating the price-distance tradeoff using spot tipping fees may be severely biased.

Although the IV strategy I presented above significantly mitigates the bias, examining the industry structure and testing the potential bias of the estimation of the price-distance tradeoff is useful. The lack of data on hauling entity and landfill ownership over time prevents detailed discussion on the economies of scale and scope. I use the information on landfill ownership in 2015 to explore the number of firms by county, and waste share by firm in California. I then assume the ownership information in 2015 reflects the ownership during 1995–2015 and check the estimate of the price-distance tradeoff using the subsamples of counties where superfirms are present (having a landfill within 60 miles of a county population center).[18]

Figure C1a in online Appendix C.3 shows the number of landfills in California owned by a

[17] In June 2016, WCNX and PROG merged into WCNX.

[18] Indeed, changing in landfill ownership in reality is not often due to the high commitment in opening a landfill. US Environmental Protection Agency (2016) notes the passage of federal environmental regulations (e.g., Subtitle D of RCRA in 1991) made properly constructing, operating, maintaining, and closing landfills more expensive. A life cycle of a landfill is typically 60 years. The first 10 years have the highest operating costs for the pre-operation that involves site surveys, permit application, and construction. The next 20 years are for actively receiving waste and the latter 30 years are for post-closure care.

firm, the number of counties served by a firm, and the firm's trash share of California waste. Three superfirms offer waste management services in California. By California trash share in 2015, they are Republic Services (25.2%), Waste Management (19.3%), and Waste Connections (6.8%). Each of them receives waste from about 20-28 counties and has landfills within 60 miles of the county population centers in 23-30 counties. However, although the superfirms own about 8-13 landfills in California, over 70 landfills are owned by other various private firms and public municipalities. This suggests a likely substantial degree of competition in waste disposal services in California.

At the county level, Figure C1b reports the median number of landfills and trash share by firm per county (conditional on counties from which the firm receives waste). The figure shows a superfirm is rarely a monopolist in a county. The average trash share per county of a superfirm is often below 25%. Figure C2 reports the number of landfills and the number of firms by county. The figure shows that except for six counties that account for less than 0.2% of waste in California, each of the other counties is served by at least two firms. In fact, most counties each sends waste to at least three firms and can travel to at least five alternative landfills owned by at least four alternative firms within 60 miles of the population centers.

Overall, the trash share per county by firm and the number of landfills and firms by county suggest a substantial degree of competition and a typical oligopoly picture of the solid waste industry in California.[19] Table C3 in the online appendix reports the estimates using subsamples of counties where superfirms are present. The estimates are very similar to the results of the main analysis, ensuring the estimates of the demand in the paper are reliable.

### 3.6.4 Expectation

Given the huge costs of opening a landfill, a disposal facility may contract with a hauler to ensure a stable and substantial incoming waste stream. In exchange, the hauler can get discounted prices on volume. Besides the contract opportunity with a landfill, the hauler may engage in a contract with the municipality to provide waste-collection services. Walls (2005) mentions that the collection contract can leave the hauler to find a landfill to accept the collected waste or can require the hauler to dispose of waste at a designated landfill (either owned by the municipality or by a private landfill that the municipality separately contracts with). These contracts can range from 3 to 10 years.

[19]This is not very surprising despite the presence of superfirms. The US Environmental Protection Agency (2016) mentions the US has approximately 100 private companies that own and operate currently active landfills, ranging from large companies that own numerous landfills throughout the country to local businesses that own a single landfill. Mergers and acquisitions in this industry have also been carefully scrutinized by the US Department of Justice, demonstrated by cases from the 1980s to 2010s, *US v. Waste Management, Inc., et al.* (1988), US, *New York Pennsylvania and Florida v. Waste Management, Inc., et al.* (1998), *US v. Waste Industries USA, Inc.* (2005), *US v. Waste Management, Inc. and Deffenbaugh Disposal, Inc.* (2015), etc.

All those contracts introduce contract affiliation and incentivize the forward-looking behaviors of haulers. Specifically, an affiliated hauler tends to be less responsive to prices in the short run than unaffiliated haulers, because it often either has facility (brand) loyalty or want to avoid the costs of switching a facility. On the other hand, the affiliated hauler may look forward and form an expectation over the future tipping fees and the costs of discarding waste, making it more responsive to prices. A dynamic model of demand can incorporate the forward-looking behavior by including the future costs of discarding waste in the hauler's decision today. Compared with the dynamic model, the static demand model in this paper understates the price elasticity. The reason is the static model assumes the hauler responds to the change in price and restricts the response at and within the assessment time rather than assuming the hauler anticipates and responds to the change over time.[20] This assumption on the time frame of the price response also implies the static model estimates the price elasticity in the short run, whereas the dynamic model gives the estimate in the long run.

Even with the estimate of the price elasticity in the short run, the model in this paper does not separate the price elasticity of affiliated haulers from that of unaffiliated haulers, because I do not observe the affiliation status. Given the affiliated haulers are less responsive to prices, one might worry about the usefulness of the estimate in this paper. In particular, would affiliated haulers, especially those that have long term contracts with the municipality regarding collection services, respond to the change in price if facilities adjust prices in response to NIMBY laws as the paper predicts? Figure F1 in online Appendix F exhibits a piece of the contract between a hauler and Del Rey Community, a census-designated place in Fresno County, California, signed in June 2020. It shows the hauler may pass the increase in its costs to the District or elect to terminate the contract, demonstrating the hauler's capability to respond to changes in tipping fees imposed by regulation or the disposal facilities.

# 4 The economic costs of intercounty waste restrictions

## 4.1 Measures of interest

Given the underlying primitives of the structural model, I conduct several counterfactual NIMBY experiments and evaluate the new spatial distribution of waste disposal and the costs a county would incur. Two counterfactual policies are considered. Import bans outlaw intercounty waste

[20] In the case of product affiliation (or contract affiliation in this paper), besides the forward-looking behaviors of consumers, firms also have incentives to look forward by setting dynamic prices. For example, they may reduce today's price to lock in consumers and adjust the price later. MacKay and Remer (2022) are studying the implications of product affiliation (consumer inertia) on dynamic pricing of oligopolists. In their estimation of the demand for retail gasoline, they find the dynamic model of demand gives higher price elasticity than the static model, conditional on unaffiliated consumers. They also find affiliated consumers have lower price sensitivities than unaffiliated consumers.

flows. Import taxes tax waste flows that cross county lines. As for the outcomes of interests, I consider the impacts on exported waste, imported waste, average tipping fees paid to dispose of waste, average miles for shipping waste to travel to a facility, and the following measures.

**The cost of NIMBY: Additional costs of discarding waste.** When a NIMBY law is enacted, haulers in a county face a new set of available facilities and/or changes in tipping fees and transportation costs. These changes may alter the haulers' choices of where to dispose of waste and generate additional costs of discarding collected waste. Assuming the haulers pass these additional costs onto the county of waste origin, the waste-discarding cost the county incurs due to the policy is

$$\Delta EC_{mt} = \frac{1}{-\beta_p}\left[\ln\left(1+\sum_{j\in\tilde{\mathbb{M}}_{mt}}\exp(\tilde{V}_{jmt})\right)\right] - \left[\ln\left(1+\sum_{j\in\mathbb{M}_{mt}}\exp(V_{jmt})\right)\right],$$

where $V_{jmt} = \beta_p\text{price} + \beta_d\text{distance}_{mj} + \beta_l\text{local}_{mj} + \gamma_j + \delta_t$; $\tilde{\mathbb{M}}$ and $\tilde{V}$ are the choice set and mean values correspond to the values when a NIMBY law is imposed.[21]

**The benefit of NIMBY: Household valuation of import reduction.** Because NIMBY enactments are motivated by the desire to reduce out-of-county waste in one's backyard, the benefits of a NIMBY law can be characterized by household preferences for imported waste and exported waste. Although the paper does not accommodate the estimation of the household utility as a function of imported and exported waste, the household utility can be assumed to be lowered with more imported waste and to be unaffected by exported waste. With this assumption, the required change in household surplus to value a one-ton reduction in imports to justify the cost of the policy is

$$\Delta\text{household surplus} = \frac{\Delta EC_{mt}}{-\Delta\text{imported waste}_{mt}}.$$

Specifically, if the policy reduces imported waste in a county at additional costs of discarding waste, the formula refers to how much households in the county would need to value a one-ton reduction in imports to justify the cost of the policy. If the policy reduces both imported waste and costs of discarding waste, the formula gives the additional household surplus per ton of import reduction. If the policy increases both imported waste and the costs of discarding waste, the formula gives the additional costs for household preference to reduce imports. If the policy increases imported waste while reducing the costs of discarding waste, the formula shows the compensation for the import increases. Households would be better off if the compensation were greater than their preference to reduce imports.

[21]The formula follows the log-sum formula of expected utility when the random disturbance of utility follows type I extreme value distribution.

**External costs of transportation.** Another variable of interest, although it is not intended by NIMBY motivation, is the change in external costs of transportation. As Austin (2018) notes, transportation incurs external costs to society that are not paid directly by shippers or consumers. These costs include wear and tear on roads and bridges, delays caused by traffic congestion, injuries and property damages due to accidents, and harmful health effects due to air pollution along the shipping routes. Austin (2018) estimates these costs range from 2.62 to 5.86 in 2014 cents/ton-mile. I use the lower bound, specifically, 1.91 cents/ton-mile (in 2000 cents), to calculate the minimum changes in freight external costs associated with the changes in ton-mile of waste shipments due to NIMBY laws.

## 4.2 Results

### NIMBY imposed at a single county

I first begin with a single-county scenario in which only Marin County imposes a policy. Later, I present the results in a top-down policy scenario in which every county imposes the policy. Assessing the policy impact in a single-NIMBY-enacting scenario is useful to track the mechanism of the impact under the assumption of all-else-being-equal. In this scenario, I choose Marin as the county that imposes a NIMBY law, because Marin has the highest exposure of waste imports to the white community, which is supposedly the most affluent community and has the most resources to make political and regulation changes. Marin is also in the San Francisco Bay Area, which receives a large amount of waste from San Francisco, which does not have its own facility. Online Appendix D.2 shows the results when NIMBY laws are imposed in Solano County, which has the second-highest exposure of waste imports to minority communities in California and is in the San Francisco Bay Area.[22]

Table 3 summarizes the results. I separately report the average tipping fees (excluding taxes) charged by a facility (henceforth price) and the average tipping fees (including taxes, if any) paid by haulers in a county of waste origin (henceforth tipping fees). The purpose of reporting prices at the facility level is to understand how facilities adjust prices in response to policies, whereas the purpose of reporting tipping fees at the waste-generating-county level is to understand the change in fee payment paid by haulers in a county, which would become the cost of the waste-generating county. Panel A lists the change in price at the facility level. The price change is then broken down into price change at facilities in Marin and other counties. I then report the change in intercounty waste in all of California. Panel B reports the changes in the following statistics in Marin: exported waste amount, imported waste, tipping fees, mileage (waste miles traveled), discarding cost (total costs of discarding waste that accounts for tipping fees, transportation, and facility characteristics

[22] King County has the highest exposure of waste imports to the non-white community in California.

as calculated in the previous section), external costs of transportation (as associated with the change in waste miles traveled), and the required household surplus per a one-ton reduction in imports that justifies the discarding cost. Panel C reports the changes in the counties other than Marin as averages per county.

Column (1) reports the results if Marin imposes an import ban. I first discuss the change in price at facility level and later discuss the change in waste quantity. Theoretically, a facility setting a price needs to balance the cost markup with the price elasticity of the demand. As shown in the estimation, the facilities in our context have economies of scale, implying that if the potential amount of waste to be received falls, the facility would likely set a high price to cover the increase in marginal costs. However, setting a high price would cause the facility to lose its market share, not only in the local market but also with potential non-local customers.

Facilities in Marin, because they would receive less waste than before, due to an import ban, would tend to increase prices to cover higher marginal costs. On the other hand, if these facilities charge higher prices, they could lose their local market shares to nonlocal facilities. That is, haulers in Marin could export waste to nonlocal facilities that would then become relatively cheaper. The incentive to keep local market shares would mitigate the incentive to increase prices to cover costs. In the end, under the import ban, the facilities in Marin would increase prices by 4.33% ($3.80/ton), because they would lose all of the imported waste anyway and would need to cover the increase in marginal costs. As a comparison, we see that under the import tax (Column (2)), the facilities would reduce their prices to avoid losing many local as well as nonlocal shares.

Facilities in the other counties, because they would now be able to receive waste that was exported to Marin, could lower prices without lowering their markups, as long as they still have economies of scale. However, because one facility can serve multiple counties, lowering prices could help them attract a huge amount of waste from other places, not only as substitutes for exports to Marin. If a facility nearly reaches or has reached the lowest marginal-cost level, receiving a substantial amount of waste will push the facility into the diseconomies-of-scale area where the marginal cost increases in the waste amount. In such a case, the facility would tend to increase price to cover the higher marginal cost.

Column (1) shows, on average, the facilities outside Marin would reduce their price by 22 cents/ton. Broken down by county, Panel B in Table D1 in online Appendix D shows facilities in some counties that exported waste to Marin or would become substitutes for Marin would increase their prices by a few cents, but facilities in Sonoma (which exported waste to Marin) and Lake (which would become a substitute for Marin) would reduce their prices considerably, by $15.81/ton and $7.50/ton, respectively, making them new dumping hotspots.

Regarding the change in waste quantity, the import ban would help Marin prevent imported waste by reducing 100% of their imports, about 181,000 tons. Therefore, the other counties would

TABLE 3: Change in intercounty waste flows after imposing counterfactual policies in Marin

| | base-line | (1) import ban equilibrium model | (2) import tax (10%) equilibrium model | price inc. tax |
|---|---|---|---|---|
| *Panel A: Change at facility level:* | | | | |
| price change | 37.14 | -0.18 | -0.06 | |
| ($/ton) | | (-0.48%) | (-0.16%) | |
| price at Marin | 87.7 | 3.8 | -0.76 | 7.94 |
| ($/ton) | | (4.33%) | (-0.87%) | (9.05%) |
| price at the others | 36.66 | -0.22 | -0.05 | |
| ($/ton) | | (-0.6%) | (-0.14%) | |
| *intercounty waste in CA* | 4,649,287 | 12,040 | 59,900 | |
| (ton) | | (0.26%) | (1.29%) | |
| *Panel B: Change in Marin County:* | | | | |
| export | 41,018 | 36,950 | 945 | |
| (ton) | | (90.08%) | (2.3%) | |
| import | 180,637 | -180,637 | -37,195 | |
| (ton) | | (-100%) | (-20.59%) | |
| tipping fees | 79.99 | -3.69 | -1.32 | |
| ($/ton) | | (-4.61%) | (1.19%) | |
| mileage | 23.61 | 4.33 | 0.28 | |
| (mile) | | (18.34%) | (1.19%) | |
| discarding cost ($/ton) | | 2.09 | -0.8 | |
| external transport cost | 88,021 | 16,161 | 1,046 | |
| ($) | | (18.36%) | (1.19%) | |
| household value ($/ton) | | 2.25 | -4.18 | |
| *Panel C: Change in other counties, average per county:* | | | | |
| export | 91,423 | -566 | 1,337 | |
| (ton) | | (-0.62%) | (1.46%) | |
| import | 101,560 | 4,379 | 2,207 | |
| (ton) | | (4.31%) | (2.17%) | |
| tipping fees | 37.97 | -1.06 | -0.91 | |
| ($/ton) | | (-2.79%) | (-2.4%) | |
| mileage | 21.18 | 0.3 | 0.26 | |
| (mile) | | (1.42%) | (1.23%) | |
| discarding cost ($/ton) | | -0.31 | -0.37 | |
| external transport cost | 308,071 | 1,205 | 1,106 | |
| ($) | | (0.39%) | (0.36%) | |
| household value ($/ton) | | 933.68 | 1,597.76 | |

reduce their exports, but only by about 600 ton per county, while increasing imports by about 4,000 tons of imports. In fact, the intercounty waste amount in California would *increase* by 12,000 tons.

The reason is that the price increase at facilities in Marin and the price reduction elsewhere would cause three remarkable changes in intercounty waste flows in California. First, dumping in Marin would become expensive for local haulers, causing them to divert Marin's waste to outside Marin. Exported waste in Marin would increase strikingly by 90% (one fifth of the import reduction). Second, some counties would become new dumping hotspots (e.g. Sonoma and Lake) because they would receive waste that was exported to Marin, as well as a substantial amount from other places given the large price reduction. For example, Sonoma would receive back about 20,000 tons of its generated waste (18% of its exported waste to Marin) but 95,000 tons in new imports. Lake would receive 82,000 tons in new imports, including the substitute for Marin and additional imported waste; see Panel B in Table D1.

Third, some counties that neither exported waste to Marin nor would become substitutes for Marin would experience changes in their waste flows or discarding costs, because of the spillover of price adjustment. Those counties are more than 80 miles from Marin, with Kings being 200 miles away; see Panel B in Table D1 in Appendix D. Note that even if prices were not adjusted, the effect of a NIMBY enactment on intercounty waste would be ambiguous due to two effects working in opposite directions. First, a county would divert waste exported to a NIMBY-enacting county to local facilities in the county of waste origin, thereby reducing intercounty waste by increasing intracounty waste. Second, a county would divert waste exported to a NIMBY-enacting county to other counties, illustrating the intercounty substitute effect. Panel A in Table D1 breaks down the change by county to empirically clarify the intracounty and intercounty substitute effects, when prices were not adjusted.

Given those changes in prices, Marin would incur additional costs to discard their waste. By exporting waste to other counties, haulers in Marin would pay lower tipping fees by \$3.69/ton, but they would travel an extra 4.33 miles and cost the society at least additional \$16,000 in external transportation costs. The extra traveled miles and the switch to nonlocal facilities would outweigh the savings in tipping fees and totally cost an extra \$2.09/ton for Marin. Households in Marin would need to value an import reduction at \$2.25/ton to balance out the extra costs of discarding waste.

In the other counties, although they would import more waste than before (on average per county), the discarding cost of their generated waste would fall by \$2.09/ton because of significantly lower tipping fees. Hence, if each county benefits by \$933.68/ton for import reduction, the drop in the discarding cost could compensate for the increase in imports.

Column (2) reports the results if Marin were to impose a tax rate of 10% on out-of-county imports. Similarly to the import ban, the total intercounty waste in California would increase. Most facilities would reduce their prices, including facilities in Marin. As mentioned above, theoretically, the price change at facilities in Marin is ambiguous, because they would need to charge higher prices to cover higher marginal costs due to the loss of imported waste, but would also need to avoid losing the current local customers due to the high prices. In contrast to the import ban, which would definitely lead them to lose all nonlocal customers and cover the higher marginal costs, the facilities in Marin in the tax scenario would be able to keep both local and nonlocal customers by reducing prices and bearing part of the tax. Results show they would reduce the price by 76 cents/ton.

Despite charging a lower price, the price at the facilities in Marin after tax would be significantly higher, by $7.94/ton, for nonlocal customers. This, together with the decrease in the average price at facilities outside Marin, would undermine the impact of an import tax on imported waste in Marin as well as on intercounty waste in California, compared with the fixed-price scenario. In fact, similar to the import ban in the presence of price adjustment, the prices at the facilities in some counties (Solano and Lake) would drop substantially to attract haulers that exported waste to Marin and other counties, making these counties new hotspots. On average, a county other than Marin would increase exports by 1.5% and imports by 2.2%, causing the intercounty waste in California to increase by 1.3% (60,000 tons).

Because prices in both Marin and other counties would fall, haulers in Marin would pay lower tipping fees at local as well as nonlocal facilities. Hence, the cost of discarding waste for households in Marin would fall by $1.32/ton. Given their reduction in imports by 37,000 tons, households in Marin would see an additional surplus of $4.18/ton in import reduction. For households in the other counties, the decrease in the discarding cost would justify the increase in their imports if their current import-reduction value is less than $1,600/ton.

**Top-down NIMBY**

In the top-down policy scenario, a NIMBY enactment is imposed in all counties in California. This universal implementation would limit the intercounty substitution effect, because all out-of-county options would either be restricted or too expensive relative to the local options.

Column (1) in Table 4 shows the results if all counties were to implement an import ban on out-of-county waste.[23] Because the ban would direct haulers in all counties to deposit waste within the county of waste origin, the reduction of exports and imports in every county would fully contribute to reduction in intercounty waste in California. On average, each county would reduce exports

[23]The reported numbers are averages over 45 counties (markets), although California has 58 counties. The reason is six counties have all of their waste transported beyond 60 miles and are excluded from the main sample of analysis. These counties, Humboldt, Mendocino, Modoc, Plumas, Siskiyou, and Trinity, generated 0.58% of total waste in California in 2010. Additionally, six counties, Alpine, Amador, Del Norte, Nevada, San Francisco, and Tuolumne, export all of their waste to other counties. These six counties accounted for 1.91% of 60-mile waste (or 1.89% of total waste) in California in 2010. Two counties, Sutter and Yuba, have a joint waste management system and are considered one unit in the analysis.

TABLE 4: Change in intercounty waste flows after counterfactual policies

| | | (1) import ban | (1b) | (2) import tax (10%) | (2b) |
|---|---|---|---|---|---|
| | base-line | equi. model | Δtotal q or Δintercnty q | equi. model | Δtotal q or Δintercnty q |
| *Change at facility level:* | | | | | |
| price change | 37.14 | 5.84 | | 0.42 | |
| ($/ton) | | (15.72%) | | (1.13%) | |
| at intercounty sites | 39.19 | 5.56 | -28,448 | 0.69 | -6,386 |
| (Δ price or Δ quantity) | | (14.19%) | -73,774 | (1.76%) | -4,813 |
| at intracounty sites | 34.25 | 6.25 | 16,367 | 0.04 | 8,845 |
| (Δ price or Δ quantity) | | (18.25%) | 0 | (0.12%) | 3,897 |
| *intercounty waste in CA* | 4,649 | -4,649 | | -142 | |
| (K tons) | | (-100%) | | (-3.05%) | |
| *Change per county:* | | | | | |
| export | 503,627 | -503,627 | | -46,170 | |
| (ton) | | (-100%) | | (-9.17%) | |
| import | 226,212 | -226,212 | | -6,212 | |
| (ton) | | (-100%) | | (-2.75%) | |
| tipping fees | 40.25 | 2.16 | | 0.52 | |
| ($/ton) | | (5.37%) | | (1.29%) | |
| mileage | 23 | -3.36 | | 0.05 | |
| (mile) | | (-14.61%) | | (0.22%) | |
| discarding cost ($/ton) | | 4.63 | | 0.47 | |
| external transport cost | 1,807 | -240 | | 4 | |
| (K $) | | (-13.29%) | | (0.21%) | |
| household value | | 276.37 | | 8,170.79 | |
| ($/ton) | | | | | |

*Note:* The table reports changes and percentage changes (in brackets) from a baseline level to a new level due to counterfactual polices. Each statistic is calculated for every county market and then averaged over markets using market sizes (total trash generated) as weights to get the above reported average. All measures use 2010 levels.

by more than 500,000 tons and imports by 200,000 tons. Note the import average per county is smaller than the export average, because a county tends to export to multiple counties, and a few counties do not export, resulting in more counties that import waste than export waste. Ultimately, the intercounty waste amount of 4.6 million tons in California would be completely phased out. Because intercounty waste is generally long-haul waste, the phase-out of intercounty waste would lead to a reduction in the transportation cost and its associated external cost by at least $240,000 (13%).

Regarding the change in price at facilities, similarly to the case of Marin-NIMBY enactment, intercounty sites would potentially receive less waste than before, due to the import ban. Hence, they would increase the price by \$5.84/ton on average to cover higher marginal costs given the economies of scale and the loss in intercounty trash share. At intracounty sites, they could lower their prices, because the potential waste they would receive, diverted from NIMBY-enacting counties, could enable the sites to operate at lower marginal costs. However, in contrast to the case of NIMBY enactment in a single county, intracounty sites would not need to lower prices to compete with alternative intercounty sites to attract the diverted intercounty waste, because the ban would be imposed in all counties. Hence, intracounty sites could increase prices without losing potential waste received. Column (1) shows they would increase prices by \$6.25/ton (18%).

The price increase in response to the import ban would cause haulers in a county to incur an additional discarding cost of \$4.63/ton. When the cost was passed to households, they would need to value import reduction at least \$276.37/ton to balance out the discarding cost.

Column (2) reports results if all counties were to implement import tax of 10% on out-of-county waste. Average price (before tax) would increase by 42 cents/ton. Intercounty trash sites would increase the pre-tax price by 69 cents/ton to cover the higher marginal costs due to the potential loss of intercounty trash share. By contrast, intracounty sites would increase the prices only by 4 cents/ton to attract the potential intercounty waste that would be either diverted either to a local site or an alternative nonlocal site. Note that by keeping low prices, the intracounty sites could compete not only with the intercounty sites within the same county to get the exported waste that would be diverted back to the county of waste origin, but also with the trash sites in other counties to receive new waste imports, making the intracounty sites themselves become new intercounty sites. Column (2b) shows an intracounty site would receive approximately 9,000 tons in additional waste and 4,000 tons of which would be out-of-county imported (intercounty) waste.

Overall, the primary result of the effects of a NIMBY tax is that the price adjustment would exacerbate the intercounty substitute effect: exported waste flow could be substituted by other exported waste flow, potentially generating extra waste miles traveled and associated external costs of transportation. Total intercounty waste in California would fall by only 3% (142,000 tons). On average, a county would reduce 9% of exports (46,000 tons) and 3% of imports (6,000 tons). Because of the strong intercounty substitute effect, the waste miles traveled would slightly increase rather than decrease, generating an extra \$4,000 in the external costs of transportation. A county would pay an additional discarding cost of 47 cents/ton, which would make households in the county value import reduction at at least \$8,000/ton to balance the cost.

# 5 NIMBY and the distribution of waste disposal by race

As mentioned, this paper also focuses on the EJ perspective of NIMBY laws, by considering the distribution of waste flows by race. First, I explore the current distribution of waste shipments by race in California. I use the census data in 2010 to reflect the most recent picture of the demographic distribution. The data come with population by race at the census block level, and household income at the block-group level.[24]

Following the literature, I define the community unit at disposal facilities for my analysis. Previous studies show correlation between environmental hazards and demographics can be quite sensitive to the definitions of community; see Anderton et al. (1994), Sheppard et al. (1999), and Mennis (2002). Data aggregated at high levels, such as a county, have been documented to be less reliable as indicators of disproportionate burdens than data aggregated to smaller units, such as census block groups or blocks. However, the choice of whether to use blocks, block groups, or census tracts as communities may also be problematic, because these units vary considerably in geographic size. For example, blocks in California range from 1/1,000,000 of a square mile to more than 1,000 square miles. Hence, I use aggregate demographic data at the smallest census units available, namely, blocks, to construct demographic data for fixed-circle communities surrounding disposal sites. A block is considered to be in the affected community if its centroid location is in the fixed circle surrounding the facility. Population counts at blocks are aggregated for counts in the community.[25]

For the main analysis, I use 3-mile buffer zones to refer to affected communities near disposal facilities. Online Appendix D shows the results for 1-mile buffers, 2-mile buffers, 4-mile buffers, and 5-mile buffers. Table 5 reports mean demographic composition in 3-mile affected communities. The table also contrasts the demographic composition at the county level in terms of receiving trash versus generating trash. In 3-mile affected communities, the average population is 26,000, of which 49.6% are white, 2.7% are black, 8.1% are Asian, and 35.0% are Hispanic. When weighted by the trash amount at a facility, percentages of white, black, Asian, and Hispanic residents are 44.2%, 3.7%, 13.2%, and 35.4%, respectively. The differences between unweighted and trash-weighted percentages by race imply more waste is disposed of in minority communities than in white communities. The disparity is also evident when comparing unweighted and receiving-trash-weighted percentages by race at the county level. One apparent reason is that minority groups live near or in urban areas that generate a lot of waste. This argument is supported by the fact that percentages of minority groups in counties increase after being weighted by waste-generating quantity, compared with unweighted levels. Therefore, considering the correlation between race and trash share conditional on each given county (market)–rather than waste quantity–is more compelling. Another interpretation of the correlation between trash share and race is whether race is a factor

[24]Median household income at census-blocks is confidentially restricted. Public data are available at the block-group level as the smallest unit.

[25]Information that is not available at blocks, such as the number of households, is first assigned from block-group values to block based on population shares, and then distributed to the communities. This approach is also used in Banzhaf and Walsh (2008).

TABLE 5: Summary statistics of demographics at waste-generating county vs. receiving community

| | 3-mile buffer | | receiving county | | generating county | |
|---|---|---|---|---|---|---|
| | unweighted | weighted | unweighted | weighted | unweighted | weighted |
| % white | 49.64 | 44.27 | 52.36 | 39.74 | 54 | 39.35 |
| | (24.74) | (20.88) | (18.5) | (10.82) | (19.26) | (11.61) |
| % black | 2.73 | 3.73 | 3.44 | 5.8 | 3.38 | 5.92 |
| | (3.62) | (3.92) | (3.4) | (3.42) | (3.31) | (3.31) |
| % Asian | 8.13 | 13.16 | 7.11 | 12.67 | 7.27 | 13 |
| | (11.99) | (12.02) | (7.16) | (6.9) | (7.95) | (7.12) |
| % Hispanic | 35.04 | 35.38 | 32.93 | 38.21 | 31.19 | 38.2 |
| | (25.41) | (22.3) | (16.96) | (11.19) | (17.28) | (11.72) |
| median hh | 41,203 | 51,259 | 35,860 | 39,007 | 35,867 | 38,587 |
| income | (16,017) | (14,860) | (8,249) | (8,049) | (10,195) | (6,719) |

*Note:* This table shows summary statistics of the population in waste-receiving communities versus waste-generating communities. Receiving communities are presented as receiving counties and nearby communities. A nearby community is defined by a 3-mile radius centered around a trash site. Population counts for the nearby communities are aggregated from 2010 census blocks that have their centroid location in the buffer. Median household income at a block is the one at its block group. The table contrasts the unweighted average population level and the average level weighted by waste amount.

that affects the probability that a disposal facility is chosen.[26]

I now examine the correlation between race and trash share. Because waste is shipped by haulers, the focal interest is the correlation after controlling for economic incentives of haulers, especially disposal prices and transport costs. Formally, the specification is a (type 2) Tobit model to account for many observations of zero trash shares:

$$s^*_{mjt} = \beta_1 \% Race_j + \beta_2 \text{income}_j + \beta_3 \text{price}_{jt} + \beta_4 \text{distance}_{mj} + \gamma_t + \delta_c + \epsilon_{mjt},$$

where $s^*_{mjt}$ is a latent variable. The observed dependent variable $s_{jmt}$ is the waste amount generated by county $m$ to be disposed of at facility $j$ out of total waste generated by county $m$ in quarter $t$ in year 2010. The observed trash share $s_{jmt}$ equals the latent variable for positive values of the latent variable, and 0 otherwise ($s_{jmt} = s^*_{jmt}\mathbf{1}(s^*_{jmt} > 0)$). The main explanatory variable of interest is $\% Race_j = \frac{\text{\#people of the race in facility j's community}}{\text{\#people in facility j's community}} \times 100$, which is the population of the race of interest as a percentage of the population in the affected community. The control variable $\text{income}_j$

[26]Note we are considering horizontal EJ. That is, does one place receive more trash than others? One can think of vertical EJ: Do majority areas send trash to minority areas? This paper focuses on horizontal EJ rather than vertical relation. Table 5 shows the racial composition in counties after being weighted by the waste-generating amount and the level after being weighted by the waste-receiving amount are similar, implying no inequity in the vertical relation. Table F1 in online Appendix F reports the summary statistics of demographics at value level instead of percentage level.

is the median household income in the community surrounding facility $j$. I also include quarter fixed effects $\gamma_t$ and market fixed effects $\delta_c$. The regression is weighted by market size (total trash generated in a county) and uses observations in year 2010.

TABLE 6: Current distribution of county waste share in 3-mile neighborhoods of facilities

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Dependent var. | market share ($\times 100$) | | | | | | |
| % black | 0.02 | 0.28 | 0.27 | 0.87*** | 0.84*** | 0.70*** | 0.55** |
| | (0.24) | (0.28) | (0.28) | (0.25) | (0.22) | (0.23) | (0.27) |
| % Hispanic | -0.03 | 0.14** | 0.13** | 0.10 | 0.07 | 0.07 | 0.06 |
| | (0.05) | (0.06) | (0.07) | (0.08) | (0.06) | (0.06) | (0.06) |
| % Asian | 0.05 | 0.02 | 0.03 | -0.08 | -0.05 | -0.04 | -0.05 |
| | (0.09) | (0.07) | (0.07) | (0.08) | (0.07) | (0.08) | (0.08) |
| income ($K) | | 0.31*** | 0.29*** | 0.37*** | 0.31*** | 0.29*** | 0.25*** |
| | | (0.07) | (0.08) | (0.09) | (0.08) | (0.08) | (0.09) |
| price | | | 0.05 | 0.07 | 0.09 | 0.06 | 0.05 |
| | | | (0.07) | (0.08) | (0.07) | (0.07) | (0.07) |
| distance | | | | -0.49*** | -0.52*** | -0.54*** | -0.54*** |
| | | | | (0.09) | (0.08) | (0.08) | (0.08) |
| railway access | | | | | 7.30*** | 6.36*** | 5.53** |
| | | | | | (2.25) | (2.43) | (2.46) |
| private | | | | | | 3.88 | 4.95** |
| | | | | | | (2.45) | (2.49) |
| days in a year | | | | | | | 0.05 |
| | | | | | | | (0.04) |
| quarter FE | Y | Y | Y | Y | Y | Y | Y |
| ori cnty FE | Y | Y | Y | Y | Y | Y | Y |
| observations | 1,478 | 1,478 | 1,478 | 1,478 | 1,478 | 1,478 | 1478 |
| non-zero obs | 1,114 | 1,114 | 1,114 | 1,114 | 1,114 | 1,114 | 1,114 |

*Note:* This table reports coefficients of a Tobit model, weighted by market size (total waste generated by a county). The dependent variable is market shares, that is, the share of a generating county's waste to a facility. Demographic characteristics of facilities are characteristics of the community within 3 miles of a facility. The sample only includes observations in 2010. The Tobit regression includes quarter fixed effects and waste-origin-county fixed effects.

Table 6 reports results. Column (1) shows no significant differences are found in the receiving waste amount between minority and white communities. However, controlling for income, more waste is sent to black and Hispanic communities (Column (2)). We see the coefficients of the black percentage and Hispanic percentage become bigger and statistically significant, implying facilities in black and Hispanic communities receive more trash for reasons unrelated to income.[27]

[27] In contrast to population that is interpolated to affected communities from block levels, median household income is interpolated from block-group levels. Hence, income in the neighborhood of a facility highly reflects income of the

Column (3) shows the disparities in waste received between black, Hispanic communities and white community persist after controlling for the disposal prices. The persistence implies prices at facilities in black and Hispanic communities differ little from prices at facilities in white communities.

Column (4) shows the coefficient of the Hispanic percentage becomes smaller and statistically insignificant after controlling for distance. This change suggests facilities in predominantly Hispanic communities are mostly near the population center of waste-generating counties. With the low transport costs, these facilities attract haulers and receive more waste than usual.

Surprisingly, the coefficient of the black percentage becomes statistically and economically significant after controlling for price and distance. A one-percentage-point increase in the percentage of the black population living near a trash site (on a mean of 3.34%) is associated with an increase of 87 basis points in the percentage of market share. This finding implies facilities in predominantly black communities offer some factors beyond prices and transport costs that benefit haulers. For example, facilities in these areas may offer benefits such as flexible operation hours, easily accessible highways, high acceptance rates due to low hassle costs that require haulers to divert collected trash before disposing of it at landfills, and so on. Columns (5)–(7) provide instances by including additional variables such as whether the facility has access to railway (*railway access*), whether the facility is owned by a private entity (*private*), and the number of days the facility is open in a year (*days in a year*).[28] These additional variables, which are expected to be attractive features of a disposal facility, positively affect the trash share that goes to a facility. Furthermore, with the control of these variables, the estimates for the demographic coefficients become smaller, implying these variables also explain the uneven distribution of waste flows by race.

Note that questions about environmental injustice are still open. Other factors may still make facilities in black communities attractive to haulers. One factor that is important for policy design, though not tested in this paper, is a facility's environmental condition. For instance, do facilities in black communities not comply with environmental standards? Such facilities may become attractive to haulers because they accept all types of waste from haulers; that is, they have low hassle costs to haulers. Such a situation would connect with the hypothesis that noncompliance might happen due to the limited political resources of black residents. Additionally, weak compliance may be related to the discriminatory regulatory enforcement hypothesis that Gray and Shadbegian

broad region, which indicates the regional economy condition, thereby correlating with the waste amount generated by households in the region. For this reason, the main interest is in the correlation between waste shipments and race rather than between waste shipments and income.

[28]These variables are available in the facility profile data by Waste Business Journal. Time series of these variables are not available. In fact, according to WBJ manager, James Thompson, these variables change little over time. Hence, they are treated as facility fixed effects in the main structural model of waste flows. For the snapshot analysis of year 2010, Table 6 includes these variables to give examples of factors beyond prices and transport costs that affect waste flows and hence distribution of waste disposal by race.

(2004) and Shadbegian and Gray (2012) mention in the cases of pulp and paper mills or manufacturing plants.

The goal of this paper is not to provide an exhaustive list of explanations for the uneven distribution of waste flows, nor does the analysis indicate the causal effect of race on waste shipments. Instead, I emphasize the extent to which prices and transport distance can explain the uneven distribution of waste disposal by race. This understanding is important to anticipate whether NIMBY laws would generate unintended consequences on the distribution of waste flows by race.

The snapshot analysis of year 2010 demonstrates three points. First, conditional on income, the current distribution of waste disposal flows by race is disproportionate: facilities in minority communities are more likely to receive trash. Second, the disparity in waste received between facilities in Hispanic communities and in white communities is mainly due to low transport costs to the facilities in Hispanic areas. Third, the disparity between facilities in black communities and in white communities is mainly caused by attractive features beyond prices and transport costs at the facilities in black areas.

These findings predict that if NIMBY enactments reduce intercounty waste, they will likely increase waste going to Hispanic areas. The reason is intercounty waste is mostly long-haul waste. Hence, directing intercounty waste back to local facilities implies waste will likely end up in facilities in Hispanic communities that are relatively close to the population centers. On the other hand, waste sent to facilities in black areas may fall, because these facilities are far away from the population centers (and attractive for other features).

TABLE 7: Change in percentages of waste of CA going to affected communities after NIMBY laws

| | | (1) | (2) | (3) | (4) |
|---|---|---|---|---|---|
| | | NIMBY enactment in Marin | | NIMBY enactment in all counties | |
| | baseline (%) | import ban | import tax (10%) | import ban | import tax (10%) |
| whites | 43.5 | -0.09 | -0.15 | -1.38 | 0.11 |
| | | (-0.2%) | (-0.3%) | (-3.2%) | (0.3%) |
| blacks | 3.45 | 0.01 | 0.05 | -0.03 | 0.01 |
| | | (0.3%) | (1.4%) | (-0.9%) | (0.3%) |
| Asians | 13.26 | -0.01 | 0.08 | -0.17 | 0.14 |
| | | (-0.1%) | (0.6%) | (-1.3%) | (1.1%) |
| Hispanics | 36.39 | 0.07 | 0 | 1.67 | -0.28 |
| | | (0.2%) | (0%) | (4.6%) | (-0.8%) |

Table 7 reports the distribution of waste disposal by race after implementing NIMBY in Marin or in all counties in California, using the structural models assuming fixed prices and equilibrium-price response presented in the previous section. The table computes the percent of waste in

California that ends up at disposal facilities, by race and ethnicity of affected communities for the baseline estimates (before counterfactuals) and the percentage-point changes after polices. Specifically, assuming waste that is sent to disposal facility $j$ equally affects all people living within three miles of the facility location, the percentage of waste imposed on white communities is

$$\%\text{ trash to white} = \frac{\sum_c \sum_{j \in J_c} \overbrace{q_{mj}/\text{population in j's buffer}_j}^{\text{trash per capita in community j}} \times \#\text{whites in j's buffer}_j}{\underbrace{\sum_c \sum_{j \in J_c} q_{mj}}_{\text{total trash generated in CA}}}.$$

Columns (1)–(2) report the results following enactment of a NIMBY law in Marin County, where white and affluent residents are most exposed to waste received and would try to restrict imported waste. As expected, the percentage of waste going to white communities would decrease, because waste going to Marin would decrease; recall Table 3.

Columns (3)–(4) report the results of enactment of a NIMBY law in all counties in California. Results show that except for the import-tax scenario, the percentage of waste that would cross county border to export to Hispanic residents would fall, but the total percentage of waste ending up in Hispanic communities would increase. Meanwhile, the total percentage of waste sent to white communities would fall. This finding implies waste would substitute away from facilities in white areas toward Hispanic communities. This result is expected from the analysis of the status quo: facilities in predominantly Hispanic communities tend to be near the population centers of waste-generating counties. For this reason, the NIMBY enactments that would reduce long-haul shipments of waste by diverting the trash to closer facilities would increase waste to facilities in Hispanic areas.

In the case of an import tax, the percentage of waste going to Hispanic communities would fall slightly. The switched sign is due to the insignificant change in intercounty waste in California; recall Table 4. In fact, the waste miles traveled in this scenario would increase slightly, implying waste would be transported farther away from the population centers where facilities in predominantly Hispanic areas are mostly located nearby. However, given the small magnitudes of the results, a more reasonable conclusion is that the distribution of waste by race would change only slightly.

Whereas NIMBY laws would increase waste to Hispanic communities, the policies would produce almost no changes in waste sent to black areas. Waste sent to black residents would generally remain the same or decrease by a modest amount and less than the reduction in white communities (under the trash tax). The reason is that facilities in black neighborhoods offer other benefits despite their high dumping fees and distant locations. As revealed in the analysis of the status quo in Table 6, potential reasons are factors strongly correlated with facility fixed effects, flexible operation hours, ownership type, and perhaps acceptance rates, hassle costs to haulers, and so on. Although providing an exhaustive list of reasons for that attractiveness is beyond the scope of this paper, the findings suggest policies that target disposal fees and transport costs do not effectively reduce waste to black communities. For example, if facilities in black communities easily accepted trash from haulers because the facilities do not properly follow the environmental standard, policies that aim to strictly inspect and/or enforce the standards in these facilities would be more effective than market-based instruments.

# 6 Conclusion

This paper studies the inefficiency costs of NIMBY laws in terms of the costs of discarding waste for haulers and hence the county of waste origin in the short and medium run when disposal facilities can adjust disposal fees in response to the regulations. I do not account for the long-run effects whereby facilities could make entry, exit, or capacity adjustments in response to the laws. I find NIMBY laws could increase total interjurisdictional waste flows if they were implemented in a single jurisdiction. Once implemented at all jurisdictions, NIMBY laws would reduce transboundary waste transportation but with significant costs.

The paper also considers the environmental justice perspective of NIMBY laws and finds the universal implementation of NIMBY would not reduce the current uneven distribution of waste disposal by race in California. A universal import ban in all counties in California would even exacerbate the disproportionate distribution. The reason is that reducing long-haul shipments of waste implies increasing waste to facilities in Hispanic communities, because these facilities tend to be near population centers of waste origin.

The paper leaves some open questions for future research. First, I do not consider the potential nonlinearity of damages and effects. Studies on waste management suggest nonlinear damages exist, both in waste amount and age of a facility (US Environmental Protection Agency (2016) and Mataloni et al. (2016)). The reason is the amount of landfill gas, a byproduct of the decomposition of material in municipal solid waste in landfills, nonlinearly depends on the waste amount, waste composition, and age of landfills. Landfill gas contains roughly 50% methane and 50% carbon dioxide, which adversely affects the environment and human health; see Vinti et al. (2021) and WHO (2015). Note the mixed evidence of the impact of a waste disposal facility on human health, evidence of the diminishing impact of proximity, and degree of waste hazard also imply the nonlinear (potentially discrete) relation between the trash site and human health.

If very large facilities cause non-linear damages, moving waste from one facility to another may not completely net out in terms of the welfare impacts. Thus, the nonlinear and cumulative damages may undermine the benefits of moving waste from one facility to another in the short run. Even if the transfer continues to happen over a long period of time, which allows the benefits of the transfer to be accumulated, the nonlinearity of the damages will generate an ambiguous change in welfare between the past and the future. The reason is that whether having two medium-size landfills causes smaller damages than a huge one and a tiny one depends on the specific nonlinear feature of the damage function.

The nonlinear damages also matter for the distributional concerns. The cumulative impacts potentially intensify the environmental justice perspective this paper is looking at. Given the paper finds waste is currently more likely sent to facilities in communities with a high percentage of minorities, the nonlinearity of the damages will imply the minority communities will suffer higher damages than other communities. Hence, exploring the nonlinear aspects of damages and effects will be an interesting and important subject for future research.

Second, facilities in black communities are relatively attractive to haulers for other reasons beyond disposal fees, transport costs, railway access, ownership type, and operation hours. Exploring these factors can help in the design of more appropriate "protection" policies. For example, several states that advocate NIMBY argue on the grounds of the protection of public health and safety. However, if disposal facilities in some areas are preferred because they intentionally do not maintain the proper environmental standards, enforcing those standards will be more effective than NIMBY taxes and import bans.

Third, the welfare change in the affected communities is worth considering. Have the affected communities been compensated for the jobs and profits the disposal facilities offer? Do minorities move to these areas for these opportunities, and are they better off than previously?

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