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NIMBY taxes matter: the case of state hazardous waste disposal taxes

Arik Levinson*

University of Wisconsin-Madison and NBER, Madison, USA

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Abstract

This paper links the theoretical and empirical literatures on interjurisdictional tax and regulatory competition, focusing on the case of state hazardous waste disposal taxes. It begins by demonstrating that local environmental taxes can be inefficient, and that the inefficiency depends on the tax elasticity of polluters' responses. The paper then uses panel data from the Toxics Release Inventory to estimate the magnitude of the tax elasticities, and to demonstrate the empirical relevance of the theoretical inefficiency of local taxes. © 1999 Elsevier Science S.A. All rights reserved.

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1. Introduction

NIMBY, an acronym for 'not in my backyard,' describes laws designed to prevent undesirable activities from occurring locally. The term has been applied to prisons, sewage treatment plants, group homes for the mentally disabled, and waste disposal facilities. The NIMBY taxes studied here are those taxes that have been imposed during the last decade by states attempting to avoid becoming the repository for other states' hazardous waste. This paper describes, theoretically and empirically, efficiency consequences of those taxes.

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*Tel.: +1-608-262-9890; fax: +1-608-263-3876.
E-mail address: amlevins@facstaff.wisc.edu (A. Levinson)

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Theories of interjurisdictional tax competition date back at least to Oates (1972), which notes that redistribution of income from mobile factors will not be possible at the local level if local jurisdictions compete to attract those factors. In Oates' model, taxes provide local public goods, and any mobile factor being taxed in excess of local public benefits received will move to other jurisdictions, seeking more favorable tax treatment. Elaborations of Oates' intuition include work by Epple and Zelenitz (1981), Gordon (1983), Mintz and Tulkens (1986), Zodrow and Mieskowski (1986), Wilson (1986, 1987) and Wildasin (1988).[1]

A parallel literature has evolved describing interjurisdictional regulatory competition, mostly by relabeling the local public good 'environmental quality' and the tax 'environmental regulation.' This literature includes Oates and Schwab (1988), Markusen et al. (1995) and Levinson (1997). Collectively, this work on interjurisdictional tax and regulatory competition provides a list of necessary conditions under which interjurisdictional competition will be efficient. If there are many homogeneous jurisdictions whose local governments maximize their citizens' welfare, and no local redistribution, no interjurisdictional externalities, and no constraints on the available tax instruments, and all production profits are earned locally, then interjurisdictional competition can be shown to be Pareto efficient.

Clearly this long list of criteria is unlikely to describe reality, which might lead us to the normative conclusion that interjurisdictional competition is necessarily inefficient. However, the empirical literature on tax and regulatory competition finds little evidence that taxes or regulations affect firm locations, employment, investment, or trade. For example, Papke (1991) uses a panel of data on state taxes and new plant locations, and a fixed-effects count-data model, to show that a measure of carefully constructed industry-specific, marginal, effective state tax rates has a negative but not statistically significant effect on plant locations. In the environmental regulatory literature, the evidence is even more scarce. Jaffee et al. (1995) conclude their survey of this literature by noting that ''there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness.'' In sum, though the theoretical models find that interjurisdictional competition is inefficient, the empirical literature suggests that the point is moot, because economic activity does not respond significantly to the different taxes and regulations in competing jurisdictions.[2]

This paper links these theoretical and empirical literatures, focusing on the case of hazardous waste disposal taxes. Hazardous waste disposal confers few benefits on local jurisdictions, and has perceived high costs, and therefore likely results in the NIMBY form of interstate competition—an escalation of disposal fees above

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[1] Thorough reviews of this theoretical tax competition literature can be found in Wilson (1996), and in Mieskowski and Zodrow (1989).

[2] Wildasin and Wilson (1996) make this point explicitly in an overlapping generations model with interjurisdictional tax competition, noting that if factors are completely immobile, tax competition amounts to lump-sum transfers among jurisdictions with no efficiency consequences.

their optimal level. Section 2 begins by constructing a simple theoretical model of interjurisdictional competition, highlighting characteristics particular to hazardous waste transportation and disposal, and deriving the relationship between the inefficiency of local taxes and the elasticity of disposal with respect to those taxes. Sections 3 and 4 use panel data on disposal taxes and interstate shipments of waste to measure empirically those elasticities. Together, the theoretical and empirical analyses demonstrate that these NIMBY taxes do matter—that their theoretical potential for inefficiency is not moot, and may well be leading to an inefficient allocation of hazardous waste transport and disposal among US states.

2. A model of hazardous waste taxation

My purpose in this section is not to replicate the findings of the existing theoretical literature, but rather to use a stripped-down version of those models to illustrate how the inefficiency of interjurisdictional competition depends on the elasticity of economic activity with respect to taxes and regulatory costs. Suppose that there exist M jurisdictions indexed $j = 1 \ldots M$. Each jurisdiction begins with some fixed level of industrial activity. Each citizen in jurisdiction j derives utility from y_j, a composite consumption good, and disutility from e_j, a public bad associated with the amount of hazardous waste disposed of nearby: $U_j = U_j(y_j; e_j)$. The public bad, e_j, is taken as exogenous by individuals. It may depend on many factors, including the jurisdiction's amount of hazardous waste disposal, W_j, and its area, a_j.[3] Because states often distinguish locally generated waste from imported waste, hazardous waste disposal is divided into two components: the amount disposed of by domestic (local) generators, W_j^{D}, and the amount disposed of by foreign (out-of-state) generators, W_j^{F}. The public bad can then be written $e_j = e(W_j^{\mathrm{D}} + W_j^{\mathrm{F}}, a_j)$,[4] and each citizen's utility is

$$U_j = U_j(y_j; e(W_j^{\mathrm{D}} + W_j^{\mathrm{F}}, a_j)). \tag{1}$$

Let individuals have exogenous incomes, I_j, that vary by jurisdiction. In addition, they receive their share of the profits from local firms generating hazardous waste,[5] and their share of revenue from taxing the disposal of hazardous waste. Individuals' budget constraints are thus

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[3] The area of the jurisdiction is included because many studies have shown that people's aversion to hazardous waste facilities declines with distance (Mitchell and Carson, 1986; Smith and Desvousges, 1986). The larger the area, the more distant such facilities are likely to be from population centers.

[4] Although W_j^{D} and W_j^{F} are perfect substitutes in production of e_j, states in this model will want to tax them differently in order to export some of the incidence of the tax.

[5] Local profits here stand for local producer and consumer surplus, which may be derived from increased labor demand, lower product transportation costs, higher land rents, or other local benefits of proximity to manufacturing.

$$y_j = I_j + \frac{1}{n_j}\pi_j + \frac{1}{n_j}(\tau_j^{\mathrm{D}} W_j^{\mathrm{D}} + \tau_j^{\mathrm{F}} W_j^{\mathrm{F}}), \tag{2}$$

where n_j is the population of jurisdiction j, π_j are profits from local production, τ_j^{D} is the tax rate jurisdiction j imposes on disposal of hazardous waste by domestic firms, and τ_j^{F} is the tax rate jurisdiction j imposes on disposal of hazardous waste by foreign firms.

Firms use competitively supplied inputs to produce y_j, the composite consumption good, and in the process generate hazardous waste, g_j. Normalizing the price of output to one, local profits are

$$\pi_j = f^j(g_j) - q_j g_j \tag{3}$$

where $f^j(\cdot)$ is a production function and q_j is the marginal cost of disposing of hazardous waste, g_j. Prices and quantities of other inputs and taxes of other jurisdictions are considered exogenous, and local producers are assumed to maximize local profits, π_j.

In the process of maximizing profits, firms minimize costs by disposing of waste in the single least expensive manner, which may mean shipping it to another jurisdiction. The least expensive disposal option for a firm in jurisdiction j has marginal cost

$$q_j = \min(\tau_j^{\mathrm{D}}, \{\tau_k^{\mathrm{F}} + cd_{jk}\colon j \neq k\}) \tag{4}$$

where c is the cost per mile of shipping waste and d_{jk} is the distance in miles between jurisdictions j and k.[6] Eq. (4) thus provides the minimum disposal cost, accounting for disposal taxes and shipping expenses.

Assume that local regulators maximize their constituents' utility, Eq. (1), with respect to τ_j^{D} and τ_j^{F}, and subject to Eqs. (2)–(4), taking into account firms' maximization of Eq. (3). The first-order condition with respect to the tax rate on hazardous waste disposal by foreign generators is

$$W_j^{\mathrm{F}} + \tau_j^{\mathrm{F}}\left(\frac{\partial W_j^{\mathrm{F}}}{\partial \tau_j^{\mathrm{F}}}\right) = -n_j\left(\frac{\partial U_j/\partial e_j}{\partial U_j/\partial y_j}\right)\left(\frac{\partial e_j}{\partial W_j^{\mathrm{F}}}\right)\left(\frac{\partial W_j^{\mathrm{F}}}{\partial \tau_j^{\mathrm{F}}}\right). \tag{5}$$

Regulators should increase the tax rate on imported waste until the marginal revenue (left-hand side) is equal to the marginal social disutility from the public bad (right-hand side). Note that both sides of Eq. (5) are negative. Raising the disposal tax on foreign generators makes the environment cleaner and generates

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[6] This ignores the pre-tax price of hazardous waste disposal. These prices are contained in private contracts between transporters and waste facilities, many of which are owned by the same corporations, and so are empirically unobservable (Peretz and Solomon, 1995).

more revenue. If there were no externality, and this were merely an exercise in tax exporting, then jurisdictions would raise the tax until the marginal revenue was equal to zero, or $W_j^{\mathrm{F}} + \tau_j^{\mathrm{F}}(\partial W_j^{\mathrm{F}}/\partial \tau_j^{\mathrm{F}}) = 0$. Because of the added benefit of a cleaner environment, the tax is higher than this revenue-maximizing point.

If local disposal is least costly, then local generators will dispose of all waste locally, $g_j = W_j^{\mathrm{D}}$, $q_j = \tau_j^{\mathrm{D}}$ and the first-order condition with respect to the tax rate on hazardous waste disposal by domestic generators is[7]

$$\frac{\partial f^j}{\partial g_j}\frac{\partial g_j}{\partial \tau_j^{\mathrm{D}}} = -n_j\left(\frac{\partial U_j/\partial e_j}{\partial U_j/\partial y_j}\right)\left(\frac{\partial e_j}{\partial W_j^{\mathrm{D}}}\right)\left(\frac{\partial W_j^{\mathrm{D}}}{\partial \tau_j^{\mathrm{D}}}\right). \tag{6}$$

Eq. (6) differs from Eq. (5) in that superscript Ds replace superscript Fs, and the left-hand side consists only of the effect of domestic disposal taxes on domestic generation. Eq. (6) indicates that the marginal private cost of the local tax (reduced output) should be set equal to the marginal social benefit of the tax (reduced local disposal).

To compare the domestic and import tax rates (τ_j^{D} and τ_j^{F}), note that $\partial e_j/\partial W_j^{\mathrm{D}} = \partial e_j/\partial W_j^{\mathrm{F}}$, and that therefore the right-hand sides of Eq. (5) and Eq. (6) differ only in the last term, $\partial W_j^{\mathrm{D}}/\partial \tau_j^{\mathrm{D}}$. Furthermore, one can use the fact that profit-maximizing firms will set $\partial f^j/\partial g_j = \tau_j^{\mathrm{D}}$, along with the social equalities in footnote 7, to rewrite Eq. (5) and Eq. (6) (with jurisdiction subscripts suppressed)

$$\tau^{\mathrm{F}} = K\left(1 - \frac{1}{\eta^{\mathrm{F}}}\right)^{-1} \tag{7}$$

$$\tau^{\mathrm{D}} = K\left(1 - \frac{1 - g/W^{\mathrm{D}}}{\eta^{\mathrm{D}}}\right)^{-1} \tag{8}$$

where

$$K = -n\left(\frac{\partial U/\partial e}{\partial U/\partial y}\right)\left(\frac{\partial e}{\partial W}\right)$$

is the social marginal cost of waste disposal, and

$$\eta^F = -\left(\frac{\partial W^{\mathrm{F}}}{\partial \tau^{\mathrm{F}}}\right)\left(\frac{\tau^{\mathrm{F}}}{W^{\mathrm{F}}}\right) \text{ and } \eta^{\mathrm{D}} = -\left(\frac{\partial W^{\mathrm{D}}}{\partial \tau^{\mathrm{D}}}\right)\left(\frac{\tau^{\mathrm{D}}}{W^{\mathrm{D}}}\right)$$

are the tax elasticities of foreign and domestic waste disposal, respectively. Eq. (7) is simply the optimal price for a single-price monopolist whose marginal cost is K.

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[7] Eq. (6) has been simplified by noting that from a social perspective the firm's marginal domestic tax payments and the state's marginal domestic tax revenues cancel: $g + \tau^{\mathrm{D}}(\partial g/\partial \tau^{\mathrm{D}}) = W^{\mathrm{D}} + \tau^{\mathrm{D}}(\partial W^{\mathrm{D}}/\partial \tau^{\mathrm{D}})$.

As a single-price monopolist, the jurisdiction will always want to operate on the elastic portion of the demand curve ($\eta^{\mathrm{F}}>1$). Therefore the jurisdiction will want to set $\tau^{\mathrm{F}}>K$. In other words, the optimal tax on imported waste will be higher than the social marginal cost of waste disposal due to the fact that the jurisdiction exports some of the incidence of that tax to residents of other jurisdictions.

Eq. (6) and Eq. (8) were derived assuming that states minimize costs in such a way that they will either export all waste or none. This means that either $W^{\mathrm{D}}=0$ or $W^{\mathrm{D}}=g$. If $W^{\mathrm{D}}=0$, the state disposes of none of its own waste, then τ^{D} is irrelevant. If $W^{\mathrm{D}}=g$, the state disposes of all of its own waste, then Eq. (8) indicates that $\tau^{\mathrm{D}}=K$, which is the social marginal cost of waste disposal. In other words, all interjurisdictional issues are absent and the tax is equal to the first-best Pigouvian tax, K. Combined with the result of the previous paragraph, that $\tau^{\mathrm{F}}>K$, this leads to the intuitive result that $\tau^{\mathrm{F}}>\tau^{\mathrm{D}}$: states will want to tax imported waste at higher rates than domestic waste.

Although Eq. (8) assumes that states export all waste or none, in a richer model a continuum of outcomes would be expected. One could imagine, for example, extending this model to include many different types of waste, each of which needs to be disposed of in a particular type of disposal facility. All the waste of a particular type from a given state would still be entirely disposed of at one site, but the sum of all waste of all types from that state would have a more complete set of disposal outcomes. Such alternative scenarios can be examined loosely, even in this simple model with homogeneous waste. If the state exports some fraction of its waste, then $g>W^{\mathrm{D}}$, but g can never be less than W^{D}, so $g/W^{\mathrm{D}}\geq 1$. Furthermore, note that $\partial\tau^{\mathrm{D}}/\partial(g/W^{\mathrm{D}})<0$, indicating that as g/W^{D} rises above 1 (the state exports some of its locally generated waste), the optimal domestic tax declines below K, all else equal, thus widening the gap between the optimal tax on domestic and imported waste.[8] Just as in the simple case where $g=W^{\mathrm{D}}$, jurisdictions will always want to tax imported waste at higher rates than locally generated waste ($\tau^{\mathrm{F}}>\tau^{\mathrm{D}}$).[9]

In most cases then, both τ^{F} and τ^{D} will be inefficient from a social perspective: τ^{F} will be too high and τ^{D} too low ($\tau^{\mathrm{F}}>K>\tau^{\mathrm{D}}$). Taxes on imported waste, τ^{F}, are borne in part by firms in other jurisdictions, and that burden is not considered by local regulators (tax exporting). Taxes on locally generated waste, τ^{D}, may shift local hazardous waste to other jurisdictions where it imposes external costs not taken into account by local regulators (pollution exporting). The extent of the inefficiency of these local taxes depends on the parameters η^{D} and η^{F}. The rest of this paper generates reduced-form estimates of those elasticities, and examines

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[8] This assumes no other policy instruments, such as waste generation taxes, are possible.

[9] To see this, note that $\tau^{\mathrm{F}}>\tau^{\mathrm{D}}$ if and only if $\eta^{\mathrm{D}}>\eta^{\mathrm{F}}(1-g/W^{\mathrm{D}})$, which will always be true because $g/W^{\mathrm{D}}\geq 1$ and η^{F} and η^{D} are both positive.

some of the implications of the model using state-level tax and hazardous waste data.

3. Data

A small but growing literature studies the economics of waste disposal. Fullerton and Kinnaman (1996) estimate the responsiveness of household trash to a fee for curbside collection. Sigman (1996) finds that hazardous waste disposal taxes have a small but observable effect on waste generation and may discourage land disposal in favor of incineration or other types of disposal, but does not focus on the potential for interjurisdictional competition. Levinson (forthcoming) uses data from the Resource Conservation and Recovery Act Information System and the Toxics Release Inventory to show that waste disposal taxes deter interstate transport. That paper uses a ‘natural experiment,’ based on changes in several discriminatory state disposal tax rates, to control for the potential endogeneity of state taxes. It compares those natural experiment results to two-stage least-squares and fixed-effects results, and to an estimate of tax responsiveness derived from the effect of distance among states on disposal shipments. But that paper does not demonstrate theoretically the efficiency consequences of the taxes. Ley et al. (1996) does describe the theoretical inefficiencies arising from constraints on interstate shipments of municipal solid waste, but though their model is calibrated using actual patterns of interstate waste transport, it does not measure the empirical responsiveness of those patterns to the tax rates.

The impetus for this particular paper is the growth of state hazardous waste disposal taxes during the last decade. Between 1987 and 1995 the number of states taxing hazardous waste disposal grew from 22 to 32, while the average tax rate more than doubled (see Table 1). Numerous motivations account for the tax increases, but for the most part they appear to have political origins. The 1980s saw the introduction of two publicly available databases that document interstate shipments of toxic and hazardous waste: the Toxics Release Inventory, and the Resource Conservation and Recovery Act Information System. These data, combined with growing national concern about the environment in general, and hazardous waste in particular, may have prompted citizens and state politicians to take action.

Massachusetts’ citizens used a voter initiative to place on the ballot a tax on the importation of toxic waste in 1992. Senator Daniel Coates ((R) Indiana) used opposition to waste imports as the centerpiece of his campaign for election to the US Senate. Former Tennessee Governor Ned McWherter once said ‘‘I don’t want New York, New Jersey, or Ohio bringing their hazardous waste into Tennessee.’’ And even Louisiana Governor Edwin Edwards, who in 1979 said ‘‘to get the jobs and the development, . . . we knowingly and advisedly accepted environmental

Table 1
Average state hazardous waste disposal taxes and interstate shipments of toxic waste

Year	States with taxes	Average state hazardous waste disposal tax ($n=48$)		TRI toxic waste shipped off-site for disposal			
		Current	$1995	Tons (1000s)	Percent shipped interstate	Percent shipped out-of-county but in-state	Percent shipped off-site but in-county
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1987	22	7.77	10.42				
1988	23	9.03	11.63				
1989	25	10.36	12.73	200	26	32	43
1990	27	13.39	15.61	209	21	45	35
1991	28	16.26	18.19	129	25	34	42
1992	30	17.20	18.68	126	27	35	39
1993	31	14.88	15.69	131	23	41	36
1994	32	15.19	15.62	117	26	37	37
1995	32	15.49	15.49	115	22	43	35

(1)–(3), calculations from Tax Day, a Commerce Clearing House publication. Taxes are average by state, where each state's tax is taken as the unweighted average tax charged to all 48 continental states, taking into account retaliatory taxes. Column (3) is inflated by the CPI-U.
(4)–(7), calculations from Toxics Release Inventory (TRI), various years.

tradeoffs,'' had changed his tune by 1994 when he proposed enacting the highest hazardous waste disposal taxes in the nation: ''This will send a message that (Louisiana) will not be a low-cost alternative for hazardous waste disposal for the rest of the country''.[10] While a complete explanation for the recent rise in state hazardous waste disposal taxes would be beyond the scope of this paper, I suspect that it has been due in part to the sudden availability of public data, legitimate growing national environmental concerns, and political expediency.

The run-up in waste disposal taxes, whatever its motivation, provides a convenient panel of data for studying empirically their effects on interstate disposal shipments. For this purpose, I have merged data from several sources. For the tax data, I have constructed a panel of annual hazardous waste disposal taxes from Commerce Clearing House publications (CCH, 1996) and from correspondence with state tax officials. To approximate annual tax rates when laws changed mid-year, I average the number of months each rate was in effect. For the few states that tax gallons of waste rather than tons, I normalize the tax by the number of gallons in a ton of water (240). I omit taxes that may be imposed by counties or other local jurisdictions, as well as most license fees that affect firms

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[10] *The Boston Globe*, 7/2/92; *The New York Times*, 9/8/91; UPI, 2/14/90; ABC Documentary, ''The Killing Grounds,'' 1979; *The Times-Picayune*, 1/25/94.

involved in hazardous waste generation, transport or disposal. These are small, relative to the disposal taxes, and they are best characterized as fixed costs (though some vary step-wise with the amount of activity).

The most notorious of the state hazardous waste disposal taxes was that enacted by Alabama in 1989: $40 per ton for disposal of waste generated by in-state waste generators, and $112 per ton for disposal of waste imported to Alabama by out-of-state generators. Supporters of the tax claimed that it more than halved the amount of waste being dumped at Alabama's giant disposal facility, and raised $30 million in annual general revenues (Walters, 1991). In 1992, the US Supreme Court declared Alabama's law unconstitutional. Nevertheless, discriminatory tariffs on out-of-state waste continue to be enacted. Some states have applied so-called 'generator' taxes to imports as well as to locally generated waste. Others rely on large per-ton transport fees, which work effectively as import taxes because they do not affect the choice of disposal location by local firms who pay the fee no matter where they send the waste. Still others have enacted retaliatory taxes that are the higher of some threshold level or the tax rate of the state from which the waste originated. Because of the retaliatory taxes, states may have separate hazardous waste tax rates for each state of origination, and the resulting panel of tax rates contains 2304 (48^2) annual observations. One consequence of the retaliatory taxes is that changes in effective tax rates have been much more numerous than would be implied solely by the number of statutory changes. Between 1991 and 1992, for example, 497 (22%) of the 2304 state-to-state taxes increased while 103 (4%) declined.

Many of these discriminatory taxes probably rest on shaky constitutional foundations, and may be subject to future Supreme Court scrutiny.[11] The Commerce Clause of the US Constitution provides ''The Congress shall have the Power . . . To regulate Commerce . . . among the several States,'' which has been interpreted to mean that states cannot themselves tax or regulate interstate commerce without prior permission from Congress. In 1978, the Supreme Court declared unconstitutional New Jersey's outright ban on imported waste, overturning a ruling by New Jersey's State Supreme Court that wastes were not 'articles in commerce,' and were therefore not subject to Commerce Clause protection. In 1989 Alabama banned imports of waste from states without adequate waste treatment and disposal facilities of their own, and this law was upheld by the trial court but declared unconstitutional on appeal. Alabama responded by enacting its $72/ton import tariff, which was overturned by the Supreme Court in 1992. Oregon State tried a 'cost-based' import duty, and that was overturned by the Court in 1994. Most recently, in 1998, a New Jersey court ruled unconstitutional New Jersey's hazardous waste transport fee, because it discriminated against interstate shipments (Amon, 1998). While many or all of these discriminatory taxes

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[11] See Urie (1995) for a comprehensive review of the constitutional issues pertaining to interstate waste shipments.

may eventually be overturned, in the meanwhile they fall disproportionately on waste imports relative to locally generated waste. Between 1989 and 1995, as many as 16 states imposed higher taxes on imported waste than on locally generated waste.

For data on interstate shipments of waste, I rely on the Toxics Release Inventory (TRI). The TRI is collected by the EPA as mandated by the 1986 Emergency Planning and Community Right-to-Know Act. It is an annual census of manufacturing establishments with 10 or more full-time employees that manufacture or process more than 25 000 pounds of any toxic chemical. Each facility reports its location, the quantity of each chemical transferred off-site, the location to which it was transferred, and the purpose of the shipment (land disposal, recycling, incineration, etc.). Though the TRI data are available from 1987 to 1995, the first 2 years are censored at high levels (75 000 and 50 000 pounds), and are generally considered less reliable than later data. Consequently, the analyses that follow examine the sum of TRI waste shipped off-site for disposal purposes for 7 years from 1989 to 1995.

In addition to data on taxes and waste shipments, the empirical models below use other state descriptive variables. From the US Census bureau, the data include each state’s population, median household income, and area. From the US Bureau of Economic Analysis comes the percent of gross state product derived from the manufacturing sector, and from the Statistical Abstract of the US comes the percent voting Republican in the 1988 presidential election. State data on hazardous waste disposal capacity are calculated from Capacity Assurance Plans filed by states complying with the federal Superfund law (EPA, 1994).

4. Empirical results

Recent years have seen significant increases in hazardous waste disposal taxes, as average disposal tax rates doubled and many states imposed discriminatory tariffs on imported waste. As a result, one would expect an increasing fraction of hazardous waste to be disposed of in the state in which it was generated. However, the aggregate data do not reveal any such response.

Table 1 presents national summary statistics on taxes and waste shipments. Between 1987 and 1995, 10 additional states began taxing off-site waste disposal, and the average tax increased by more than 75% in real terms before falling after the 1992 Supreme Court verdict. During this period, the fraction of TRI off-site disposal shipments that crossed state borders vacillated between 20 and 26%, with no clear trend. One possible explanation for the absence of a trend in interstate waste shipments may be inconsistencies in the data from year to year. The list of chemicals reported to the TRI has changed over time, and the Pollution Prevention Act of 1990 added recycling, energy recovery, and treatment to the list of reportable activities in the TRI. The drop in total disposal shipments in 1991 is probably due to erroneous classification of off-site disposal shipments prior to 1991.[12]

Table 1 also presents the percentages of waste shipped between states, within states, and within counties. Approximately one-fourth of the waste shipped off-site crosses state borders. So while the interstate analysis here is important, it may not represent the entire story. Indeed some counties have their own disposal taxes, and opposition to waste disposal may be more of a local issue than a state-wide issue. However, the vast majority of these taxes are enacted at the state level, and therefore the analyses below are conducted with state taxes and interstate shipments, rather than intercounty shipments.

Table 2 presents characteristics of states as of 1991. Column (2) contains the characteristics of only those 20 states without hazardous waste disposal taxes,

Table 2
Average State Characteristics, 1991

	All states (1)	States without HW disposal taxes (2)	States with HW disposal taxes (3)
Number of states	48	20	28
Median household income	$28 644	$28 818	$28 519
(1989)	(747)	(1261)	(930)
Population 1990	5134	3585	6241*
(thousands)	(795)	(705)	(1235)
Land area	61 656	53 582	67 423
(square miles)	(6758)	(8673)	(9772)
Population density	169	187	157*
(persons/sq. mile)	(34)	(67)	(36)
Percent over age 65	12.88	13.22	12.64*
	(0.26)	(0.48)	(0.29)
Percent with college degree	12.86	13.27	12.57*
	(0.34)	(0.54)	(0.44)
Waste generated 1991	6300	3136	8561*
(thousand tons, RCRA)	(2390)	(1610)	(3911)
Waste capacity 1989	2256	2252	2260
(thousand tons, RCRA)	(619)	(1369)	(450)
Waste imports 1991	645	164	989*
(tons, TRI)	(182)	(79)	(292)

Sample standard errors in parentheses.
*Difference in means statistically significant at 5%.
Sources: USA Counties, US Census Bureau; Commerce Clearing House; calculations from Toxics Release Inventory (TRI); and EPA (1994).

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[12] These misclassifications could affect the analyses below, but the results using the TRI are robust to the exclusion of the 1989–90 data. Also, in all of the empirical analyses that follow, I include year-specific dummy variables. The specifications thus measure the effect of taxes on the national *distribution* of waste controlling for the total amount of waste disposed.

while column (3) contains information about the other 28 continental states. States with taxes have median household incomes similar to those without taxes, but larger populations and land areas, and smaller population densities, percentages over age 65 and with college degrees. States with taxes also generate more waste, have similar waste capacity, and import much more waste from other states. This last observation complicates the measurement of the effect of taxes on waste shipments, as it suggests that states receiving more waste enact higher taxes, and that the tax rates are therefore endogenous.

It is possible to see the aggregate effect of these taxes, but only by looking at changes in tax rates over time. For example, between 1991 and 1995, 12 states increased their hazardous waste disposal taxes, while 36 states' tax rates remained constant or declined. The 36 states with non-increasing taxes saw an 11% decline in TRI imports for disposal, whereas the 12 states with increased taxes saw a 41% decline in TRI imports for disposal. So while all interstate TRI shipments declined by 22% between 1991 and 1995, the decrease was largest to states increasing their disposal taxes. While these differences provide preliminary evidence that tax increases have shifted waste away from high-tax states, both the size of the effect and its general direction are extremely sensitive to the time period examined and the grouping of states.

To examine these tax effects more systematically, I borrow from the literature on interstate human migration (DaVanzo, 1981; Schultz, 1982). Assume that the number of tons of waste going from state i to state j in any given period t, W_{ijt}, follows a conditional distribution with mean λ_{ijt}. In particular, let the conditional expectation of W_{ijt} be equal to

$$E[W_{ijt}|X_{ijt}, \tau_{ijt}, g_{it}] = \lambda_{ijt}g_{it} = \exp[X'_{ijt}\beta + \delta\tau_{ijt} + \ln(g_{it})] \tag{9}$$

where λ_{ijt} is an exponential function of X_{ijt}, the characteristics of the two states, and τ_{ijt}, the state-pair-specific tax rate, and g_{it} is the amount of waste generated in state i. The migration literature then typically estimates something analogous to

$$\ln\left(\frac{W_{ijt}}{g_{it}}\right) = X'_{ijt}\beta + \delta\tau_{ijt}\varepsilon_{ijt} \tag{10}$$

which is equivalent to estimating

$$\ln(W_{ijt}) = X'_{ijt}\beta + \gamma\ln(g_{it}) + \delta\tau_{ijt} + \varepsilon_{ijt} \tag{11}$$

where γ is constrained to be equal to 1. With human migration, such a constraint is sensible, as the dependent variable in Eq. (10) can be thought of as the log of the probability that any given person in state i will migrate to state j. The human migration probability is likely to be uncorrelated with the number of people living in state i. For waste disposal, however, there are many reasons that the probability of transport from i to j may depend on the quantity of waste generated in i. For example, if there are scale economies in treating waste for disposal, states that generate more waste may be more likely to contain an appropriate disposal facility and therefore less likely to export that waste, and γ is likely to be less than 1. Consequently, this paper focuses on variants of Eq. (11).

In addition to the tax rates, Eq. (11) includes as regressors the origin and destination states' median income, population, area, population density, hazardous waste capacity, and population percentages over age 65 and with college degrees, and the log of the origin states' hazardous waste generated, $\ln(g_{it})$. The distance between the origin and destination states, calculated as the straight-line distance between each state's population-weighted center, is also included. Other regressors include year dummies, region dummies, and an indicator for the observations in which the waste is shipped within the same state.

Table 3 contains estimates of the transport Eq. (11). The dependent variable is the log of TRI off-site disposal shipments among states. The 7 years of data for the 48 continental states yield 16 128 observations (7×48^2). Because many of the annual state-pairs had zero waste shipped, and to avoid taking the logarithm of zero, the dependent variable is actually $\ln(W_{ijt}+1)$. As a reference point, column (1) of Table 3 contains OLS results for the pooled data. The quantity of interstate shipments declines with the distance between states, and the squared distance term indicates that the effect diminishes slightly as distance increases. Relatively more waste is shipped from states that have large, dense, and old populations, large areas, and less hazardous waste disposal capacity. The coefficient on ln(waste generated) is between zero and one, suggesting that proportionately less waste is shipped from states generating more waste, all else equal. Regarding the destination state, relatively more waste is shipped to poorer, more densely populated, younger and less educated states, and to states with greater waste disposal capacity. The negative year coefficients reflect the steady decline in off-site waste disposal.

Two biases afflict the specification presented in column (1) of Table 3. First, the tax variable is endogenous, as can be seen by its significant positive coefficient. Second, of the 16 128 observations, 12 377 have dependent variables equal to zero. This suggests that the data may be considered censored, and that therefore the coefficients may be biased. The remaining columns of Table 3 correct for these problems.

The first problem involves the endogenous tax variable. States that for unobserved reasons import more waste may respond by imposing higher taxes. In other words, ε_{ijt} may be correlated with taxes, τ_{ijt}. Recall from Table 2 that more waste is imported to states with hazardous waste taxes than to those without taxes. The positive tax coefficient in column (1) is probably the spurious result of the effect of hazardous waste imports on taxes rather than the effect of taxes on imports.

Suppose, instead, that Eq. (11) can be written

$$\ln(W_{ijt}) = X'_{ijt}\beta + \gamma \ln(g_{it}) + \delta\tau_{ijt} + \theta S_j^* + \mu_{ijt} \tag{12}$$

Table 3
Waste shipments and state characteristics: 1989–95

Dependent variable: log of TRI interstate shipments for disposal	Pooled OLS (1)	Fixed effects, destination-state fixed effects[a] (2)	Fixed effects Tobit[b] (3)	Trimmed least-squares[c] (4)
Tax	0.0054*	−0.0085*	−0.0062	−0.0084
	(0.0014)	(0.0026)	(0.0074)	(0.0072)
Miles	−0.0089*	−0.0091*	−0.0260*	−0.0184*
	(0.0002)	(0.0002)	(0.0007)	(0.0011)
Miles squared (thousandths)	2.63*	2.72*	6.29*	4.24*
	(0.07)	(0.06)	(0.29)	(0.49)
Origin state median 1989 income ($1000)	−0.0162	−0.0183†	−0.0622	−0.0516
	(0.0100)	(0.0095)	(0.0410)	(0.0580)
Origin state population (millions)	0.0544*	0.0558*	0.2374*	0.1660*
	(0.0078)	(0.0072)	(0.0239)	(0.0365)
Origin state area (million sq. miles)	3.52*	3.55*	6.31*	6.82*
	(0.87)	(0.82)	(3.06)	(4.72)
Origin state density (persons/sq. mile)	0.0009*	0.0009*	0.0031*	0.0022*
	(0.0002)	(0.0002)	(0.0007)	(0.0008)
Origin state percent over age 65	0.0232	0.0227	0.2076*	0.1843†
	(0.0169)	(0.0153)	(0.0584)	(0.0983)
Origin state percent with college degree	−0.0020	−0.0002	0.3000*	0.2342*
	(0.0152)	(0.0147)	(0.0693)	(0.0856)
Origin state capacity (million tons, 1991)	−0.0089	−0.0082	−0.0562*	−0.0405†
	(0.0074)	(0.0067)	(0.0210)	(0.0236)
Origin state ln(waste generated)	0.2040*	0.2023*	0.8369*	0.7605*
	(0.0155)	(0.0149)	(0.0688)	(0.1162)
Destination state median income ($1000 1989)	−0.0735*			
	(0.0111)			
Destination state population (millions)	0.0843*			
	(0.0067)			
Destination state area (1000 sq. miles)	3.31 *			
	(1.13)			
Destination state density (persons sq. mile)	0.0017*			
	(0.0002)			
Destination state percent over age 65	−0.377*			
	(0.018)			
Destination state percent with college degree	−0.222*			
	(0.017)			
Destination state capacity (million, tons, 1991)	0.0606*			
	(0.0068)			
Same state	6.18*	5.99*	3.90*	1.97*
	(0.16)	(0.15)	(0.46)	(0.55)
Year = 1990	−0.004	0.038	0.132	0.006
	(0.097)	(0.089)	(0.310)	(0.240)
Year = 1991	−0.447*	−0.363*	−1.449*	1.347*
	(0.098)	(0.090)	(0.331)	(0.418)

Table 3. Continued

Dependent variable: log of TRI interstate shipments for disposal	Pooled OLS (1)	Fixed effects, destination-state fixed effects[a] (2)	Fixed effects Tobit[b] (3)	Trimmed least-squares[c] (4)
Year=1992	−0.514*	−0.416*	−1.595*	−1.669*
	(0.098)	(0.091)	(0.333)	(0.447)
Year=1993	−0.467*	−0.402*	−1.450*	−1.631*
	(0.099)	(0.092)	(0.329)	(0.485)
Year=1994	−0.465*	−0.396*	−1.310*	−1.538*
	(0.098)	(0.091)	(0.326)	(0.462)
Year=1995	−0.546*	−0.472*	−1.640*	−1.727*
	(0.098)	(0.091)	(0.328)	(0.513)
West	−0.778*			
	(0.089)			
Northeast	−0.248*			
	(0.098)			
South	0.031			
	(0.082)			
Constant	12.75*			
	(0.65)			
Observations	16128	16128	16128	16128
R^2	0.44	0.52		

Standard errors in parentheses (heteroskedastic-consistent for column (1)).
[a] Column (2) includes 48 destination-state fixed effects.
[b] Column (3) is a censored normal regression (Tobit) that includes 48 destination-state fixed effects.
[c] Column (4) presents trimmed least-squares estimates that account for censoring and destination-state fixed effects in an asymptotically consistent manner (Honoré, 1992).
*Statistically significant at 5%.
†Statistically significant at 10%.

where S_j^* is the unobserved 'suitability' of state j to hazardous waste disposal, and $\epsilon_{ijt}=\theta S_j^*+\mu_{ijt}$. This S_j^* might include the state's geological features or the unobserved pre-tax cost of hazardous waste disposal. Also suppose each destination state's taxes are a function of its own characteristics and lagged imports.[13] Because lagged imports will also be a function of S_j^*, taxes and omitted suitability are correlated. Because S_j^* is in the error term of Eq. (11) and column (1), the tax coefficient is biased. In this case the bias seems strong enough to reverse the sign of the coefficient.

To account for the correlation between τ_{ijt} and ε_{ijt}, I use a fixed-effects approach, assuming that omitted suitability is constant over the period 1989–1995.[14] I estimate

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[13] Note that I have assumed no direct simultaneity: *current* imports W_{jt}^{F} do not directly affect *current* taxes τ_{ijt}. If taxes take more than 1 year to be enacted, this assumption seems reasonable.

[14] Papke (1991) uses a fixed-effects approach to account for the endogeneity of state business taxes in determining new manufacturing plant openings.

$$\ln(W_{ijt}) = s_j^* + X'_{ijt}\beta + \gamma \ln(g_{it}) + \delta\tau_{ijt} + \mu_{ijt} \tag{13}$$

where s_j^* represents a vector of 48 destination-state-specific dummy variable coefficients. Column (2) of Table 3 contains estimates of Eq. (13). Aside from the tax coefficient, the magnitude and statistical significance of the other coefficients mirror those in the pooled regression from column (1). In contrast to column (1), however, the tax coefficient in the fixed-effects specification is negative and statistically significant (−0.0085). This implies that important unobserved differences among destination states make taxes seem positively correlated with imports. After controlling for these unobserved differences with simple dummy variables, that correlation is negative.[15]

A second problem with the results in column (1) is the large number of observations representing annual state-pairs between which no waste was shipped for disposal. If one interprets these observations as censored, then the coefficients are biased. Column (3) attempts to solve both the censoring and tax endogeneity problems simultaneously. It presents a censored normal (Tobit) version of Eq. (11), with 48 unreported destination-state dummy variable coefficients. Because the state fixed effects will themselves have been calculated from censored data, the results are biased (Heckman and Macurdy, 1980). Nevertheless, the general pattern of signs and statistical significance remains similar to that in column (2), though of course the magnitudes are different. The tax coefficient (−0.0062) is slightly smaller than in the linear fixed-effects model, and is not statistically significant.[16]

Finally, column (4) presents an asymptotically consistent version of a censored fixed-effects model due to Honoré (1992), and based on the trimmed least-squares estimator of Powell (1986).[17]

Honoré's estimator assumes that the residual errors, μ_{ijt}, are independent and identically distributed conditional on the regressors and the fixed effects. It capitalizes on the fact that, if coefficients are picked correctly, those residuals will be symmetrically distributed around the regression line in the uncensored region. The resulting point estimate of the tax effect (−0.0084) is nearly identical to that of the simple fixed-effects model in column (2), though the standard error is much larger. Other coefficients have similar signs and significance, and to a lesser degree similar magnitudes.

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[15] When origin-state dummies are included instead of destination-state dummies, their coefficients are statistically insignificant, and the tax coefficients are nearly identical to the pooled coefficients in column (1). This is to be expected, because omitted origin-state characteristics are unlikely to be correlated with the destination state tax rates.

[16] I have also estimated a Tobit without the (biased) fixed effects used to control for the tax endogeneity, in which case the tax coefficient (0.0273) is positive, and even larger than in column (1). This finding is typical of censored models, in which OLS estimates are biased towards zero. So while the censoring appears to impart a bias, it does not account for the positive tax coefficient.

[17] Honoré has generously posted his 'Pantob' program, Gauss code that implements the estimators in his (1992) paper, to his Princeton University web page: http://webware.princeton.edu/econometrics/programs/pantob/.

Of the two potential problems with the OLS specification in column (1), endogeneity bias and censoring, the former seems to be the most important. When destination-state fixed effects are included to deal with the endogenous taxes, the tax coefficients range from -0.006 to -0.008, depending on how the censoring is addressed. When the fixed effects are not included, the tax coefficient retains its counterintuitive positive sign.

To consider the magnitude of the tax coefficients, note that the average tax rate over the period 1989–95 was $15 (see Table 1). Consequently, the estimated elasticity of waste disposal with respect to the tax ranges from 0.09 to 0.13. These tax elasticities are considerable, given that taxes are only part of the total disposal cost. If we add the private cost or 'gate price,' which averaged $156 per ton in 1993 (Peretz and Solomon, 1995), and use the sum of average private costs and taxes as a base, the price elasticities range from 1.06 to 1.45. These large tax and price elasticities suggest that disposal in different states are close substitutes for each other.

To put the magnitudes of the tax coefficients in context, consider the fact that the average tax increase by states assessing hazardous waste taxes, from 1989 until the 1992 Supreme Court verdict, was 40%, from $20 to $28. From the point estimates in Table 3, this would generate a decline in hazardous waste imports of between 3.6 and 5.2%. Against the claim by the proponents of Alabama's $72 per-ton import tax that it halved the amount of waste being disposed in Alabama, these estimated responses seem easily plausible.

Finally, one might be concerned that different types of hazardous waste have different sets of disposal options, and that by aggregating all of the chemicals in the TRI, important distinctions have been overlooked. The model in Section 2 described a world with one type of homogeneous waste (W), and in which states maximize utility by disposing of all such waste at one locale, foreign or domestic. The empirical model in this section has aggregated wastes of all types, from relatively innocuous waste (at least in low concentrations), to the highly toxic. Furthermore, some particular chemicals have only limited disposal options. In 1992 only eight US facilities held permits to dispose of polychlorinated biphenyls (PCBs), a carcinogen commonly used in electrical transformers (Urie, 1995). The empirical results presented here, by aggregating wastes with different characteristics and different sets of disposal options, may mask wide discrepancies in the responsiveness of those wastes to disposal taxes.

To explore the disaggregate data, Table 4 examines the tax elasticities of a few subsets of the TRI. The first row of Table 4 presents the four specifications from Table 3, where the dependent variable is limited to TRI shipments of heavy metals.[18] When the endogenous taxes are controlled for with fixed effects, in columns (2) through (4), the coefficients are negative, statistically significant, and larger than for the aggregate data in Table 3. When the dependent variable is

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[18] These include 16 categories of chemicals and their compounds. The largest three categories, zinc, manganese, and copper, account for 78% of the total.

Table 4
Robustness checks: shipments of particular chemical groups

Tax coefficient from different dependent variables	Pooled OLS (1)	Fixed effects, destination-state fixed effects[a] (2)	Fixed effects, Tobit[b] (3)	Trimmed least squares[c] (4)
Log of TRI interstate shipments of heavy metals	0.0016 (0.0010)	-0.0112* (0.0019)	−0.0286* (0.0099)	−0.0234* (0.0094)
Log of TRI interstate shipments of EPA 33/50 program metals	0.0015† (0.0009)	−0.0092* (0.0018)	−0.0237* (0.0101)	−0.0222* (0.0094)
Log of TRI interstate shipments of chlorinated solvents	0.0004 (0.0006)	−0.0011 (0.0014)	0.0121 (0.0174)	0.0151 (0.0164)

Standard errors in parentheses (heteroskedastic-consistent for column (1)).

[a] Column (2) includes 48 destination-state indicator variables (fixed effects).

[b] Column (3) is a censored normal regression (Tobit) that includes 48 destination-state indicator variables (fixed effects).

[c] Column (4) presents trimmed least-squares estimates that account for censoring and destination-state fixed effects in an asymptotically consistent manner (Honoré, 1992).

*Statistically significant at 5%.

†Statistically significant at 10%.

limited to metal compounds targeted by the EPA's '33/50' voluntary reduction program, in the second row of Table 4, a similar pattern emerges.[19] However, when the dependent variable is limited to chlorinated solvents, the type of waste studied by Sigman (1996), the tax coefficients are statistically insignificant. Different types of waste undoubtedly have different properties that affect their disposal costs, disposal options, and transportation costs, and hence their responsiveness to state disposal taxes. However, with very few exceptions, their disposal taxes are based on weight, regardless of their chemical content or toxicity. Therefore, the aggregate data used in Table 3 provide the best estimate of the effect of those disposal taxes on the aggregate national patterns of hazardous waste transport and disposal.

5. Conclusions

This research has shown that state hazardous waste taxes (NIMBY taxes) matter theoretically, in that states have the incentive to set inefficiently high rates for

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[19] These five metals are cadmium, chromium, lead, mercury, and nickel.

imported waste. It has also shown that the taxes matter empirically in that they have significantly decreased shipments of waste to high-tax states, *ceteris paribus*. Combined with the theoretical evidence that local tax-setting is inefficient, these results undermine the rationale for devolving environmental policy from the federal government to state and local regulators.

6. Nomenclature

Variable	Definition
τ_j^D	Tax rate on disposal of waste generated by domestic (local) firms.
τ_j^F	Tax rate on disposal of waste generated by foreign (out-of-state) firms.
q_j	Minimum hazardous waste disposal cost for firms in jurisdiction j.
I_j	Exogenous incomes in jurisdiction j
a_j	Area of jurisdiction j.
n_j	Population of jurisdiction j.
W_j^D	Hazardous waste deposited by domestic (local) firms in jurisdiction j.
W_j^F	Hazardous waste deposited by foreign (out-of-state) firms in jurisdiction j.
π_j	Profits from local production in jurisdiction j.
g_j	Hazardous waste generation in jurisdiction j.
y_j	A composite good.
c	Transport cost per ton-mile.
e_j	Public bad caused by hazardous waste in jurisdiction j.
d_{jk}	Distance in miles between jurisdictions j and k.

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