State Taxes and Interstate Hazardous Waste Shipments

By ARIK LEVINSON*

Hazardous waste has been among the fastest growing components of environmental compliance costs in the United States (Council on Environmental Quality, 1995), and often tops public opinion polls as the most important environmental problem (Roper Organization, Inc., 1991). In recent years many states have substantially increased the rate at which they tax disposal of hazardous waste, and a few have imposed higher taxes on waste imported from other states. This research measures the extent to which these state taxes have altered interstate shipments of hazardous waste.

The topic deserves heightened attention for several reasons. First, the deterrent effect of disposal taxes on interstate shipments is not obvious from aggregate or even cross-section data: States with relatively high tax rates import relatively *more* waste. As shown in what follows, however, endogeneity of tax rates and unobserved heterogeneity typical of cross-state policy studies complicates the empirical modeling of taxes and waste flows. This project employs a panel of tax and shipment data to isolate the effect of taxes on waste flows, holding state characteristics constant.

Second, even if the direction of the effect of disposal taxes on waste shipments were obvious, its magnitude is not. Anecdotal evidence has led analysts to claim that hazardous waste disposal taxes raise revenues, deter waste imports, or both.[1] In theory, hazardous waste generators could respond to these taxes in varying degrees by reducing the amount of waste generated in the first place, by increasing the amount of waste disposed on-site or into other environmental media (air or water pollution), or by merely shifting disposal among jurisdictions to reduce tax liability. In what follows I examine the last of these options.[2]

Third, the extent to which these local taxes affect hazardous waste transport has implications for the optimal level of federal responsibility for environmental regulation (Jerome L. Stein, 1971; Sam Peltzman and T. Nicholaus Tideman, 1972). Since 1980, regulatory authority for many environmental programs has been devolving from the federal government to state and local governments, and one cannot predict a priori the effect of this change on environmental stringency. In some situations states may compete to attract polluting firms by lowering environmental standards in a "race to the bottom." In others, states may compete to deter polluting activity by hiking up standards.[3] Hazardous waste disposal, by imposing large costs and few benefits on local jurisdictions, would be expected to result in the latter form of regulatory competition—a race to the top in environmental stringency.

Finally, this research brings evidence to bear on the legal debate over the state laws that discriminate among wastes according to their origin. In 1992, in *Chemical Waste v. Hunt* the U.S. Supreme Court declared unconstitutional an Alabama fee charging an extra $72 per ton for waste imported to Alabama for disposal. Despite the Court's ruling against tariffs on out-of-state waste, such policies continue to be enacted. Some states have carefully written regulations to avoid constitutional challenge, while others may simply be taking advantage of

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[1] Alabama's $72 per-ton import fee was credited with halving the amount of hazardous waste being received by the state's largest facility, while contributing $30 million to the state's general revenues (Jonathan Walters, 1991).

[2] In part, data considerations determine the focus on transported waste, because on-site disposal and substitution to other media are less well documented. See Hilary Sigman (1996) for a study of the effect of hazardous waste disposal taxes on waste generation.

[3] Both situations have been formally modeled (Wallace E. Oates and Robert M. Schwab, 1988; James R. Markusen et al., 1995; Levinson, 1999).

lengthy legal processes to restrict interstate commerce temporarily. In addition, several recent federal bills have proposed authorizing states to ban or tax out-of-state waste.[4] If states are permitted to erect tariff barriers to hazardous waste imports, the result could be a general decentralization of hazardous waste disposal and a decline in economic efficiency and environmental safety.

I. Data

The primary data source for this project is an annual panel of hazardous waste disposal taxes for the 48 continental states for recent years, compiled from Commerce Clearing House publications and from telephone conversations with state tax officials. The calculations are complicated by the fact that many states impose "retaliatory" taxes. South Carolina, for example, currently charges either $34 per ton or the per-ton fee charged by the state from which the waste originated, whichever is higher. Each state therefore has the potential for 48 separate hazardous waste disposal tax rates, one for each state of origination, and the resulting panel of tax rates contains 2,304 (48 squared) observations per year. One consequence of the retaliatory laws is that changes in any one state's taxes are reflected in other states' effective tax rates, and the variation over time in effective taxes is greater than would be expected from the frequency of statutory changes.

In constructing the tax panel, I made several simplifying assumptions. Annual tax rates average the number of months that each rate was in effect. Tax rates expressed per gallon of waste (e.g., Maine) were converted to per-ton rates by multiplying by the number of gallons in a ton of water (239.7). I ignore taxes that may be imposed by counties or other local jurisdictions. In addition, states have a wide variety of license fees that affect firms involved in hazardous waste generation, transport, or disposal. Because most are small, relative to the disposal taxes, and because most are best characterized as fixed costs (though some vary stepwise with the amount of activity), I ignore these various licensing fees. Several states (Louisiana, Massachusetts, Pennsylvania) have imposed large per-ton transport fees. I treat these as import taxes because they do not affect the choice by local firms which pay the fee no matter where they send the waste. Similarly, many states charge generator fees and apply those fees to out-of-state waste. I consider these import taxes for the same reason: They affect the decision of waste importers only.

Data on interstate shipments of waste come from the U.S. Environmental Protection Agency's (EPA's) *1987–1993 Toxics Release Inventory* (TRI) (1995a). It is an annual census of manufacturing establishments that process more than 25,000 pounds of any toxic chemical. Though the TRI data are available annually from 1987, the first two years are censored at high levels, 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 from 1989 to 1993.

Another potential source of data on interstate waste shipments is that collected by the states under the auspices of the 1984 amendments to the Resource Conservation and Recovery Act (RCRA). RCRA defines hazardous waste as toxic, corrosive, reactive, or explosive. Although most of the hazardous waste disposal taxes studied here are based on RCRA definitions, the RCRA data are imperfect for several reasons. First, they are only available for three years: 1991, 1993, and 1995. Second, each handler of waste files separate paperwork. If waste is shipped from a generator in one state to a treatment facility in a second state, and then on to a disposal facility in a third state, both shipments appear in the RCRA data. Consequently, it is impossible to identify the origin and destination of waste shipments without double-counting some shipments. Third, because some large contiguous facilities have more than one EPA identification number, some on-site disposal may be misclassified as off-site shipments. Nevertheless, as a robustness check to the TRI results, I also report results using the RCRA data.

While the TRI is limited to manufacturing establishments, the manufacturing sector made up 58 percent of generators and accounted for 98 percent of the RCRA waste generated in

[4] See, for example, the Municipal Solid Waste Flow Control Act, proposed during the 104th Congress.

1989 (EPA, 1993).[5] The TRI is also limited to toxic wastes, omitting those that are exclusively corrosive, reactive or explosive; however, much of the RCRA waste fits this classification.[6] In sum, the RCRA data measure the volume of waste including waste water or soil, which is the measure on which local taxes are based. The TRI includes only toxic chemicals from manufacturers; however, manufacturers contribute the bulk of the RCRA volume, and most of the RCRA waste is classified as toxic.

The rest of the data used below describe characteristics of the 48 continental states. Population, median household income, area, and the percent voting Republican in the 1988 presidential election come from the U.S. Department of Commerce (various years). The percent of gross state product derived from the manufacturing sector comes from the USA Counties CD-ROM supplement to the *Statistical Abstract of the U.S.* State-level data on hazardous waste disposal capacity come from Capacity Assurance Plans filed by states complying with the federal Superfund law (EPA, 1994).

II. The Effects of Hazardous Waste Disposal Taxes on Interstate Waste Shipments

Table 1 contains aggregate figures from the tax and shipment data. The first three columns present the number of states with taxes and their average tax rates per ton. Between 1987 and 1995 the number of states taxing off-site waste disposal increased from 22 to 32, and the average tax increased by more than 75 percent in real terms before falling after the 1992 U.S. Supreme Court verdict. Note, however, that there is much more variation over time than is suggested by the changes in the overall averages. Between 1991 and 1992, for example, 497 of the 2,304 state-to-state taxes increased while 103 declined. In addition, in any given year as many as 16 states imposed higher taxes on imported waste than on locally generated waste. Despite these changing taxes, it is difficult to see their effect in the aggregate data in columns (4) through (7). Finally, as a reference, column (8) presents the total amount of RCRA hazardous waste generated. Because it includes waste water and soil, and because off-site shipments are much more concentrated, the RCRA data understate the relative environmental importance of off-site shipments. In general, if the rise in state off-site disposal taxes has deterred interstate hazardous waste shipments, that effect is not apparent in aggregate.[7]

Table 2 describes characteristics of states with and without hazardous waste disposal taxes as of 1991. Compared to states without taxes, states assessing taxes have similar median household incomes, larger populations and land areas, and smaller population densities and percentages over age 65 and with college degrees. States with taxes also generate more hazardous waste, have similar waste capacity, and import from other states vastly larger quantities of waste as measured by either the TRI or RCRA data. This last observation, that states with taxes import more waste, provides strong initial evidence that the tax rates are endogenous.

To place more structure on the problem, I estimate

$$(1)\quad \ln(W_{ijt}) = \mathbf{X}'_{ijt}\boldsymbol{\beta} + \gamma \ln(g_{it}) + \delta\tau_{ijt} + \varepsilon_{ijt}$$

where W_{ijt} is waste shipped for disposal from state i to state j during year t, $\mathbf{X}_{ijt}$ is a vector of characteristics of states i and j, g_{it} is the amount of waste generated by state i in year t, and τ_{ijt} is the state-to-state specific tax rate. Components of $\mathbf{X}_{ijt}$ include the origin and destination states' median income, population, area,[8] population density,

[5] The rest of the RCRA waste is generated by agriculture, services, mining, and government activities.

[6] Although the exact proportion of RCRA waste that would be characterized as toxic is difficult to calculate from published data, the least it could be is 37 percent and the most 79 percent (EPA, 1995b).

[7] Part of the problem reflects inconsistencies in the data from year to year. The list of chemicals and activities reported to the TRI has changed over time. The drop in disposal shipments in 1991 in column (4) is probably due to erroneous classification of off-site disposal shipments prior to 1991. These misclassifications could affect the analyses below, but the results using the TRI are robust to the exclusion of the 1989–1990 data.

[8] The area of the jurisdiction is included because studies have shown that people's aversion to hazardous waste facilities declines with distance (Robert C. Mitchell and Richard T. Carson, 1986; V. Kerry Smith and William H. Desvousges, 1986). The larger the area, the more distant such facilities are likely to be from population centers.

TABLE 1—AVERAGE STATE HAZARDOUS WASTE DISPOSAL TAXES AND INTERSTATE SHIPMENTS OF WASTE

	Average state hazardous waste disposal tax ($n = 48$)			TRI toxic waste		RCRA hazardous waste		
Year	States with taxes (1)	Current (2)	$1995 (3)	Tons shipped off-site for disposal (1,000's) (4)	Percent shipped interstate for disposal (5)	Tons shipped off-site for disposal (1,000's) (6)	Percent shipped interstate for disposal (7)	Tons generated (millions) (8)
1987	22	7.77	10.42					
1988	23	9.03	11.63					
1989	25	10.36	12.73	199	26 percent			
1990	27	13.39	15.61	207	21			
1991	28	16.26	18.19	129	25	2658	38 percent	306
1992	30	17.20	18.68	124	29			
1993	31	14.88	15.69	133	23	2487	54	258
1994	32	15.19	15.62					
1995	32	15.49	15.49			1658	53	279

Notes: Columns (1)–(3) contain 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. Columns (4)–(5) contain calculations from the *Toxics Release Inventory* (TRI), various years. Columns (6)–(8) contain calculations from Resource Conservation and Recovery Act (RCRA) data form WR, various years.

hazardous waste capacity, and population percentages over age 65 and with college degrees. The distance between the two states is calculated as the great-circle distance between each state's population-weighted center. In addition I have included year and region indicators, and an indicator for the observations in which the waste is shipped within the same state.

A. *Pooled Estimations*

Table 3 presents estimates of equation (1) in various forms. The five years of TRI data for the 48 continental states generate 11,520 observations (5×48^2).[9] As a benchmark, column (1) contains results for the pooled data, without correcting for endogeneity. 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.[10] Waste appears more likely to be 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 positive but considerably less than 1, indicating that waste is proportionately less likely to be shipped from states generating large volumes of waste, all else equal. This result makes sense if there are returns to scale in waste disposal, and states with large generators are more likely to have in-state disposal facilities. With respect to the destination, waste appears more likely to be shipped to states that have relatively poorer, more densely populated, younger and less-educated populations, and more hazardous waste disposal capacity. The year indicator coefficients describe a steady decline in off-site waste disposal over time.

The most obviously improbable result in column (1) of Table 3 is the significant positive coefficient on the tax variable (0.0051), suggesting that relatively more waste is shipped to states with high disposal taxes. A likely explanation is that states that for unobserved reasons import more waste respond by imposing higher taxes. In econometric terms, the error term in equation (1), ε_{ijt}, is correlated with the tax variable, τ_{ijt}, either because the tax rates are endogenous or because some omitted characteristics of states are correlated with both tax rates and hazardous waste imports. Table 2 shows

[9] Because many of the observations had zero waste shipped, the dependent variable is the log of shipments plus one pound.

[10] A more complicated spline yields essentially the same pattern.

TABLE 2—AVERAGE STATE CHARACTERISTICS FOR STATES WITH AND WITHOUT HAZARDOUS WASTE DISPOSAL TAXES, 1991

	States without HW disposal taxes (1)	States with HW disposal taxes (2)
Number of states	20	28
Median household income (1989)	$28,818	$28,519
	(1,261)	(930)
Population 1990 (thousands)	3,585	6,241*
	(705)	(1,235)
Land area (square miles)	53,582	67,423*
	(8,673)	(9,772)
Population density (persons/square miles)	187	157*
	(67)	(36)
Percent over age 65	13.22	12.64*
	(0.48)	(0.29)
Percent with college degree	13.27	12.57*
	(0.54)	(0.44)
Waste generated 1991 (thousand tons, RCRA)	3,136	8,561*
	(1,610)	(3,911)
Waste capacity 1989 (thousand tons, RCRA)	2,252	2,260
	(1,369)	(450)
Waste imports 1991 (tons, TRI)	198	1,023*
	(81)	(296)
Waste imports 1991 (tons, RCRA)	1,561	34,665*
	(1,556)	(10,039)

Note: Sample standard errors in parentheses.
Sources: USA Counties, U.S. Bureau of the Census; Commerce Clearing House; calculations from the *Toxics Release Inventory* (TRI) and Resource Conservation and Recovery Act (RCRA) form WR, various years.
* Difference in means statistically significant at 5 percent.

that states with hazardous waste taxes import many times as much waste as states without taxes, and the tax coefficient in column (1) of Table 3 reflects this cross-state difference.

Suppose, for example, that the true version of equation (1) is

$$\text{(2)} \qquad \ln(W_{ijt}) = \mathbf{X}'_{ijt}\boldsymbol{\beta} + \gamma \ln(g_{it}) + \delta\tau_{ijt} + \theta\tilde{A}_j + \mu_{ijt}$$

where $\tilde{A}_j$ is the unobserved suitability of state j to hazardous waste, and $\varepsilon_{ijt} = \theta\tilde{A}_j + \mu_{ijt}$. This $\tilde{A}_j$ might include characteristics such as geological suitability to hazardous waste disposal facilities or the unobserved pretax price of hazardous waste disposal.[11] Suppose further that taxes in each destination state are a function of the state's characteristics and lagged imports,

$$\text{(3)} \qquad \tau_{ijt} = f\left(\mathbf{Z}_{jt}, \sum_{i \neq j} W_{ij,t-1}\right)$$

where $\mathbf{Z}_{jt}$ are observable characteristics of state j at time t, and $W_{ij,t-1}$ are last year's imports to state j.[12] Because lagged imports will also be a function of $\tilde{A}_j$, taxes and omitted suitability are correlated. Because $\tilde{A}_j$ is omitted from column (1) of Table 3, the coefficient on τ_{ijt} is biased. In this case the bias appears strong enough to change the sign of the coefficient.

To account for the correlation between τ_{ijt} and ε_{ijt}, I take three separate approaches. The first is a "natural experiment" based on the idea that for shipments subject to retaliatory taxes, the tax rate may be considered exogenous. The second approach uses a fixed-effects model with destination-state indicator variables to try to measure the unobserved $\tilde{A}_j$. The third approach estimates the exogenous part of equation (3) and uses the predicted values of τ_{ijt} as an instrument for the actual tax rates.

B. *A "Natural Experiment"*

From 1989 to 1993, six states assessed hazardous waste disposal taxes that were the larger of some statutory value and the tax rate charged by the origin state.[13] In cases where the retaliatory tax rule was binding, the tax will not have been a function of the destination-state characteristics, observed or unobserved, equation (3) will not hold, and the tax rate in equation (1) can be considered exogenous. Consider the ex-

[11] Pretax prices are unobservable because they are contained in private contracts between transporters and waste facilities, many of which are owned by the same corporations (Jean H. Peretz and Jeffrey Solomon, 1995).

[12] Note that equation (3) assumes no direct simultaneity. In other words, current imports cannot directly affect current taxes τ_{ijt}. Because the tax laws typically take time to pass and to become effective, this assumption is reasonable.

[13] These states were Indiana, Louisiana, Mississippi, Ohio, Oklahoma, and South Carolina.

ample depicted in Figure 1. Three states (a, b, and c) each ship waste to state j. State a charges no hazardous waste disposal tax, state b charges \$20 per ton, and state c charges \$40 per ton. State j charges a retaliatory tax that is the higher of \$10 or the origin state's tax. In this example, τ_{aj} = \$10 and is endogenous. However τ_{bj} = \$20 and τ_{cj} = \$40, and both are independent of past shipments to j. Furthermore, because $\tau_{bj} < \tau_{cj}$ we can expect that $W_{bj} > W_{cj}$. To take advantage of this feature of the tax laws, I examine the subset of interstate shipments in which these retaliatory taxes bind and in which the resulting tax rates differ only because of origin-state characteristics—analogous to examining only W_{bj} and W_{cj} in Figure 1.

Column (2) of Table 3 presents estimates of equation (1) in which the sample is restricted to the 294 annual state pairs for which retaliatory taxes bind. For this subset the tax coefficient is negative (−0.0113), although it is not statistically significant at conventional levels (perhaps due to the smaller sample). Nevertheless, the result differs sharply from the significant positive tax coefficient in column (1) that includes all of the state pairs. Because the subset of states used in column (2) is small and may not be representative, and because the decision to enact a retaliatory tax may itself depend on unobserved characteristics, in other approaches I account directly for the correlation between the error term in equation (1) and taxes.

Recall that the error term in equation (1) is assumed to have two components: the unobserved suitability of state j for waste disposal, $\theta\tilde{A}_j$, and a well-behaved error term, μ_{ijt}. Their sum is correlated with τ_{ijt} because state j's tax rates are a function of lagged imports, which are also a function of state j's unobserved suitability. This suggests two alternate approaches to dealing with the correlation between ε_{ijt} and τ_{ijt}: measuring $\tilde{A}_j$ directly so as to remove it from the error term, or instrumenting for τ_{ijt}. The next two subsections describe each of these approaches and their results.

C. *Fixed Effects*

To account for omitted suitability of states to hazardous waste disposal, I use the panel of TRI data to estimate fixed-effects models, assuming that suitability is constant over the period examined:

$$\ln(W_{ijt}) = \boldsymbol{\alpha}_j^* + \mathbf{X}_{ijt}'\boldsymbol{\beta} + \gamma \ln(g_{it}) + \delta\tau_{ijt} + \mu_{ijt} \quad (4)$$

where $\boldsymbol{\alpha}_j^*$ is a vector of coefficients on 48 destination-state indicator variables.

Column (3) of Table 3 presents estimates of (4). Except for the tax variable, the pattern of coefficient magnitudes and statistical significance here is similar to those in the pooled model in column (1). Compared with the uncorrected results in column (1), however, the tax variable in the fixed-effects model is negative and statistically significant (−0.0098). This suggests that important differences among states make taxes appear to be positively correlated with imports in aggregate or cross-section analyses. When these differences are controlled for, even with simple indicator variables, the tax coefficient has the more intuitive negative sign.[14]

Because so many of the state pairs had zero waste shipped, in column (4) of Table 3 I present a Tobit (censored normal) version of equation (4). The results in column (4) are inconsistent because in nonlinear models the coefficients of interest are functions of the fixed effects, and the estimated fixed effects are inconsistent due to the censoring (James J. Heckman and Thomas E. MaCurdy, 1980; Bo E. Honoré, 1992). Nevertheless, the tax coefficient (−0.0036) remains negative, though it is statistically insignificant.

One might also suspect that *origin*-state omitted variables are correlated with both taxes and shipments, though this is unlikely because except for retaliatory taxes, disposal tax rates are

[14] Alternative fixed-effects specifications have also been explored, but are not reported here. For example, when origin-state indicator variables are included instead of destination-state indicators, they are statistically insignificant and the tax coefficients are nearly identical to those using the pooled model in column (1). This is to be expected, because unobserved origin-state characteristics are unlikely to be correlated with the destination state's tax rate. Also, when state-pair-specific indicators are included (2,304 of them), the tax coefficients are negative and statistically significant, as in column (3).

TABLE 3—WASTE SHIPMENTS AND STATE CHARACTERISTICS: TRI DATA, 1989–1993

Dependent variable: log of TRI interstate shipments for disposal	Pooled (1)	Retaliatory taxes only[a] (2)	Destination-state fixed effects[b] (3)	Tobit with destination-state fixed effects[b] (4)	Tobit with origin and destination-state fixed effects[c] (5)	Two-stage least squares (6)
Tax	0.0051*	−0.0113	−0.0098*	−0.0036	−0.0092	−0.0171*
	(0.0016)	(0.0108)	(0.0032)	(0.0085)	(0.0112)	(0.0065)
Miles	−0.0090*	−0.0166*	−0.0092*	−0.0261*		−0.0091*
	(0.0002)	(0.0023)	(0.0002)	(0.0008)		(0.0002)
Miles squared (thousandths)	2.66*	5.40*	2.74*	6.25*		2.72*
	(0.08)	(0.93)	(0.08)	(0.35)		(0.09)
Origin-state median 1989 income ($1,000)	−0.0119	0.1259	−0.0140	−0.0297		−0.0149
	(0.0120)	(0.1531)	(0.0114)	(0.0481)		(0.0134)
Origin-state population (millions)	0.0557*	0.0586	0.0577*	0.2406*		0.0585*
	(0.0093)	(0.0581)	(0.0086)	(0.0283)		(0.0089)
Origin-state area (million square miles)	3.54*	2.53	3.53*	6.35*		3.35*
	(1.05)	(8.65)	(0.98)	(3.62)		(1.06)
Origin-state density (persons/square miles)	0.0008*	0.0010	0.0008*	0.0023*		0.0008*
	(0.0002)	(0.0033)	(0.0002)	(0.0008)		(0.0002)
Origin-state percent over age 65	0.0372**	−0.0698	0.0363*	0.2826*		0.0356**
	(0.0203)	(0.1707)	(0.0184)	(0.0688)		(0.0208)
Origin-state percent with college degree	0.0103	−0.2265	0.0122	0.3408*		0.0110
	(0.0184)	(0.2486)	(0.0177)	(0.0807)		(0.0213)
Origin-state capacity (million tons, 1991)	−0.0142	−0.1344	−0.0135**	−0.0651*		−0.0135
	(0.0090)	(0.1063)	(0.0082)	(0.0249)		(0.0082)
Origin-state ln(waste generated)	0.1988*	0.0356	0.1963*	0.7789*	0.0418	0.1989*
	(0.0185)	(0.1779)	(0.0178)	0.0799*	(0.3031)	(0.0210)
Destination-state median income ($1,000 1989)	−0.0822*	0.0108				−0.1172*
	(0.0132)	(0.1332)				(0.0175)
Destination-state population (millions)	0.0896*	***				0.1365*
	(0.0082)					(0.0157)
Destination-state area (1,000 square miles)	2.28**	***				0.3457
	(1.36)					(1.2793)
Destination-state density (persons/square miles)	0.0018*	−0.0007				0.0016*
	(0.0002)	(0.0060)				(0.0003)
Destination-state percent over age 65	−0.405*	−0.3974				−0.4704*
	(0.022)	(0.5357)				(0.0304)
Destination-state percent with college degree	−0.245*	1.9389*				−0.2565*
	(0.020)	(0.3075)				(0.0219)
Destination-state capacity (million tons, 1991)	0.0685*	0.4386*				0.0707*
	(0.0081)	(0.1221)				(0.0083)
Same state	6.08*		5.88*	3.73*	22.23*	5.95*
	(0.19)		(0.18)	(0.54)	(0.66)	(0.24)
Year = 1990	0.014	0.200	0.059	0.191	0.200	0.082
	(0.096)	(0.825)	(0.089)	(0.309)	(0.398)	(0.097)
Year = 1991	−0.398*	0.299	−0.306*	−1.25*	−0.235	−0.267*
	(0.099)	(0.822)	(0.091)	(0.34)	(0.570)	(0.106)
Year = 1992	−0.474*	0.917	−0.368*	−1.42*	−0.214	−0.322*
	(0.099)	(0.868)	(0.093)	(0.34)	(0.603)	(0.109)
Year = 1993	−0.444*	−0.022	−0.373*	−1.30*	−0.038	−0.344*
	(0.100)	(0.870)	(0.094)	(0.33)	(0.615)	(0.104)
West	−0.631*					−0.548*
	(0.106)					(0.114)
Northeast	−0.113					0.172
	(0.116)					(0.145)
South	0.063					−0.007
	(0.098)					(0.094)
Constant	13.35*	−4.60				15.52*
	(0.79)	(9.19)				(1.05)

TABLE 3—*Continued.*

Dependent variable: log of TRI interstate shipments for disposal	Pooled (1)	Retaliatory taxes only[a] (2)	Destination-state fixed effects[b] (3)	Tobit with destination-state fixed effects[b] (4)	Tobit with origin and destination-state fixed effects[c] (5)	Two-stage least squares (6)
Observations	11,520	294	11,520	11,520	11,520	11,520
Zeros	8,823	187	8,823	8,823	8,823	8,823
R^2	0.45	0.54	0.53			0.44

Note: Heteroskedastic-consistent standard errors in parentheses.
[a] The relevant destination states in column (2) are Indiana, Louisiana, Mississippi, Ohio, Oklahoma, South Carolina.
[b] Columns (3) and (4) include 48 destination-state fixed effects.
[c] Column (5) includes 48 destination-state fixed effects and 48 origin-state fixed effects.
* Statistically significant at 5 percent.
** Statistically significant at 10 percent.
*** Dropped due to collinearity.

determined by destination states. To address this concern, however, column (5) presents a Tobit specification with fixed effects for both origin and destination states. All of the time-invariant state characteristics drop out, leaving only taxes, waste generation, and year indicators. The tax coefficient (−0.0092) is also negative, though it is insignificant and still biased due to the censored data. On the basis of columns (3) through (5) and footnote 14, the destination state's heterogeneity appears responsible for the endogeneity of the taxes. When this heterogeneity is accounted for, taxes are shown to have a significant deterrent effect on waste shipments.

D. *A Two-Stage Least-Squares Estimator*

A third approach to the problem posed by the endogenous tax policy is to instrument for the tax rates. Column (6) presents a two-stage least-squares (2SLS) estimate of equation (1). Three instruments are included in the first-stage regression of tax rates on the variables exogenous to waste imports: the logarithm of the amount of RCRA waste generated in the destination state, the percent of the gross state product attributed to the manufacturing sector, and the percent of voters voting Republican in the 1988 presidential election. Table 4 presents an OLS regression of tax rates on destination-state characteristics, including the three instruments. States generating more waste tend to assess

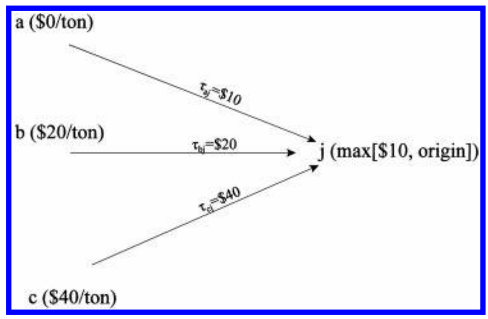

FIGURE 1. RETALIATORY TAXES

lower disposal taxes,[15] and states with more manufacturing and more Republican voters enact higher taxes, though the latter coefficient is not quite statistically significant.

The validity of each of these three instruments may be questioned. In particular, it may seem unusual to characterize waste generation as exogenous. Recall, however, that the instrument merely needs to be correlated with the endogenous regressor (τ_{ijt}) and uncorrelated with the error term (ε_{ijt}). While the first-stage regression of taxes on generation may be the reduced form of a simultaneous system, that by itself does not detract from waste generation as a valid instrument. In other words, waste

[15] Note that the coefficient on destination-state waste generation (−2.56) cannot be interpreted structurally. While states generating more waste enact lower taxes, states enacting lower taxes also probably generate more waste.

generation affects taxes (τ_{ijt}) and does not affect imports (W_{ijt}). Whether taxes affect generation is irrelevant. That said, tests of the overidentifying restrictions fail at low levels of significance, as does a Lagrange multiplier test of the joint hypothesis that equation (1) is specified correctly and that the three instruments are valid. Nevertheless, the 2SLS results are worth presenting because they represent a common technique for estimating the effect of endogenous policies, and because they broadly confirm the natural experiment and fixed-effects results.

Column (6) of Table 3 presents a 2SLS estimate of equation (1) in which predicted values of τ_{ijt} are used in place of their actual values. Here again, the tax coefficient is negative, while the rest of the coefficients remain generally unchanged. While one may question any of the three econometric approaches individually, together they support one another in showing that these taxes have had significant deterrent effects on interstate waste transport.

TABLE 4—HAZARDOUS WASTE TAXES AS A FUNCTION OF DESTINATION-STATE CHARACTERISTICS

Dependent variable: State-pair-specific hazardous waste tax	
ln(RCRA waste generated)	−2.56*
	(0.11)
Manufacturing share of earnings 1990	50.42*
	(2.75)
Percent voting Republican in 1988 presidential election	0.056
	(0.035)
Median household income 1989 ($1,000)	−1.86*
	(0.07)
Population 1990 (millions)	2.75*
	(0.08)
Area (million square miles)	−86.49*
	(6.10)
Population density (persons/square miles)	−0.008*
	(0.002)
Hazardous waste capacity (million tons, 1991)	0.72*
	(0.06)
Percent over age 65	−3.01*
	(0.13)
Percent with college degree	−0.026
	(0.081)
Same state	−6.45*
	(0.94)
Year = 1990	4.66*
	(0.50)
Year = 1991	7.57*
	(0.59)
Year = 1992	9.04*
	(0.56)
Year = 1993	6.49*
	(0.50)
West	6.21*
	(0.54)
Northeast	11.78*
	(0.91)
South	−0.49
	(0.47)
Constant	109.8*
	(4.9)
Observations	11,520 [5×48^2]
R^2	0.29

* Statistically significant at 5 percent.

III. Robustness Checks and Magnitudes

To test the sensitivity of the results to the data used, Table 5 presents the tax coefficients using the log of RCRA hazardous waste as the dependent variable and all of the same regressors as in Table 3.[16] The RCRA tax coefficients follow the same general pattern as the TRI tax coefficients. The pooled specification yields a significant positive coefficient, but when the endogenous taxes are controlled for, the tax coefficient becomes negative. In the RCRA data, the retaliatory tax coefficient is significant in row (2) while the fixed-effects coefficient in row (3) is not. Both the retaliatory coefficient in row (2) and the 2SLS coefficient in row (4) are larger than the TRI coefficients from Table 3, which is to be expected because the RCRA data measure the volume of waste including waste water and soil, while the TRI measures the quantity of toxic chemicals alone. If shippers respond to higher taxes on volume by concentrating waste (including less waste water and soil), the response as measured by the TRI will be smaller than that measured by the RCRA data. For both the TRI and the RCRA data, the tax coefficient changes from positive and significant in the pooled specification to negative and usually significant in the other specifications.[17]

[16] The only difference is that the year indicators are for 1993 and 1995.

[17] When Tobit fixed-effects models are estimated using the three years of RCRA data, their coefficients are small, positive, and statistically insignificant. Recall, however, that

Table 6 examines the magnitudes of the tax coefficients. Column (1) reports the point estimates from Table 3, and column (2) calculates the tax elasticities assuming average tax rates are $15 per ton—the average tax rate across all 48 states, including those without taxes. The tax elasticities are large, especially given that taxes are only one component of total price. Another large component, the private cost or "gate price," averaged $156 per ton in 1993 (Peretz and Solomon, 1995). Using the sum of average private costs and taxes as a base, the price elasticities calculated from the tax coefficients would range from 0.7 to 2.9, indicating that states are close substitutes as disposal options. The third column of Table 6 presents the percent change in shipments associated with a tax increase from $18 per ton to $26 per ton. This is the average increase in taxes among states that do assess hazardous waste disposal fees, from 1989 to 1993. The different approaches lead to estimates of a decline in imports ranging from 7 to 12 percent.

As a benchmark against which to compare the magnitudes of the tax coefficients, the distance coefficients are useful. The coefficients on the miles between the origin and destination states are negative and statistically significant for all four specifications in Table 3 (and for all of the RCRA specifications summarized in Table 5). Omitting the natural experiment, which has a small unrepresentative sample and a much larger distance coefficient, and the Tobit coefficients, which have slightly different interpretations due to the assumption of censoring, the distance coefficients are approximately 0.009. If firms are indifferent between a one-dollar increase in transportation costs and a one-dollar increase in disposal taxes, we can infer the price of transporting hazardous waste per ton per mile from the ratio of the mileage coefficient to the tax coefficient. Column (4) of Table 6 presents that calculation, and the predicted transport costs range from $0.53 per ton-mile to $1.47. The only published estimate of hazardous waste transport costs is $0.29 per ton-mile (EPA, 1988 [adjusted for inflation]), which falls below the predictions from the tax coefficient. One reason for the larger measured response to distance costs than tax costs might be that distances are permanent, while there is a short-term or temporary element to the estimated tax elasticities. Waste shippers may take time to adjust to disposal tax changes, perhaps because they sign long-term contracts, whereas responses to distances among states are certainly completely reflected in current transport patterns.

TABLE 5—WASTE SHIPMENTS AND STATE CHARACTERISTICS: RCRA DATA—1991, 1993, 1995

	Tax coefficient (standard error)	n	R^2
(1) Pooled	0.0108* (0.0014)	6,912	0.26
(2) Retaliatory taxes only	−0.0263* (0.0083)	226	0.50
(3) Destination-state fixed effects	−0.0040 (0.0030)	6,912	0.47
(4) Two-stage least squares	−0.0205* (0.0064)	6,912	0.20

* Statistically significant at 5 percent.

Making this benchmark calculation in reverse, it is possible to estimate the tax coefficient from the knowledge that the mileage coefficient is −0.009 and the cost of transport is $0.29 per ton per mile. Row (6) of Table 6 shows that the predicted tax coefficient would be −0.031. At an average tax of $15, this translates to a tax elasticity of 0.47, and an increase from $18 to $26 would be associated with a 21-percent drop in shipments to states raising their taxes. These estimates are high relative to those provided by the tax coefficients directly, which is to be expected if there is a temporary component to the tax elasticities while the distance elasticities are permanent. Finally, recall that the proponents of Alabama's $72 per-ton import tax argued that it halved the amount of waste being disposed in Alabama. That claim seems easily plausible given the empirical findings summarized in Table 6.

IV. Conclusions

Interstate competition in hazardous waste disposal taxes has significantly affected patterns of hazardous waste disposal in the United States in recent years, by decreasing shipments of waste to states enacting high taxes. In addition,

the bias associated with nonlinear fixed-effects models increases as the number of time periods examined shrinks.

TABLE 6—HAZARDOUS WASTE SHIPMENTS AND TAXES: MAGNITUDES

	Tax coefficient and 95-percent confidence interval (1)		Tax elasticity (2)	Change from \$18 to \$26 (3)	Predicted cost of transport (\$/ton/mile) (4)
(1) Retaliatory taxes only	−0.011	±0.021	0.17	−8 percent	\$1.47
(2) Destination-state fixed effects	−0.010	±0.006	0.15	−7	0.94
(3) Tobit with destination-state fixed effects	−0.004	±0.017	0.06	−3	
(4) Tobit with origin and destination-state fixed effects	−0.009	±0.022	0.14	−6	
(5) Two-stage least squares	−0.017	±0.013	0.26	−12	0.53
(6) Predicted from $\beta_{\text{miles}} = 0.0090$ and transport costs 29¢/ton/mile	−0.031		0.47	−21	

Tables 2 and 4 show that disposal taxes are largest and have increased most in states that have large capacity or import large quantities of waste. Together, these two conclusions imply that state hazardous waste disposal taxes have increased the decentralization of hazardous waste disposal relative to the hypothetical case in which hazardous waste disposal taxes are equal across states. If there are economies of scale or safety in centralized hazardous waste disposal, then the results here cast doubt on the wisdom of decentralizing environmental policy itself. However, transport of hazardous waste among states presents its own set of negative externalities, and a policy encouraging local disposal alleviates those problems. Without knowing the external costs of hazardous waste transport relative to the benefits of centralized disposal, it is impossible to pass judgement on the welfare consequences of hazardous waste tax competition. Nevertheless, by estimating the effect of that competition on disposal patterns, this research has shown that decentralized hazardous waste disposal appears to be one important consequence of shifting environmental regulatory responsibility to the states.

REFERENCES

Commerce Clearing House. *State tax guide*, 2nd Ed. Chicago: Commerce Clearing House, 1996.

______ . *Tax day*. Chicago: Commerce Clearing House, various issues.

Council on Environmental Quality. *Environmental quality*. Washington, DC: U.S. Government Printing Office, 1992.

Heckman, James J. and MaCurdy, Thomas E. "A Life Cycle Model of Female Labour Supply." *Review of Economics and Statistics*, January 1980, *47*(1), pp. 47–74.

Honoré, Bo E. "Trimmed LAD and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects." *Econometrica*, May 1992, *60*(3), pp. 533–65.

Levinson, Arik. "NIMBY Taxes Matter: The Case of State Hazardous Waste Disposal Taxes." *Journal of Public Economics*, 1999 (forthcoming).

Markusen, James R.; Morey, Edward R. and Olewiler, Nancy. "Competition in Regional Environmental Policies When Plant Locations Are Endogenous." *Journal of Public Economics*, January 1995, *56*(1), pp. 55–77.

Mitchell, Robert C. and Carson, Richard T. "Property Rights, Protest, and the Siting of Hazardous Waste Facilities." *American Economic Review*, May 1986 (*Papers and Proceedings*), *76*(2), pp. 285–90.

Oates, Wallace E. and Schwab, Robert M. "Economic Competition among Jurisdictions: Efficiency Enhancing or Distortion Inducing?" *Journal of Public Economics*, April 1988, *35*(3), pp. 333–54.

Peltzman, Sam and Tideman, T. Nicholaus. "Local versus National Pollution Control: Note." *American Economic Review*, December 1972, *62*(5), pp. 959–63.

Peretz, Jean H. and Solomon, Jeffrey. "Hazwaste Landfill Costs on Decline, Survey Says." *Environmental Solutions*, April 1995, *8*(4), pp. 21–25.

Roper Organization, Inc. "Environmental Protection in the 1990s: What the Public Wants." Presentation to the U.S. Environmental Protection Agency, June 1991; cited in Walter A. Rosenbaum, *Environmental politics and policy*. Washington, DC: Congressional Quarterly Press, 1995.

Sigman, Hilary. "The Effects of Hazardous Waste Taxes on Waste Generation and Disposal." *Journal of Environmental Economics and Management*, March 1996, *30*(2), pp. 199–217.

Smith, V. Kerry and Desvousges, William H. "The Value of Avoiding a Lulu: Hazardous Waste Disposal Sites." *Review of Economics and Statistics*, May 1986, *68*(2), pp. 293–99.

Stein, Jerome L. "The 1971 Report of the President's Council of Economic Advisers: Micro-Economic Aspects of Public Policy." *American Economic Review*, September 1971, *61*(4), pp. 531–37.

U.S. Department of Commerce. *Statistical abstract of the United States*. Washington, DC: U.S. Government Printing Office, various years.

U.S. Environmental Protection Agency (EPA), Office of Policy Analysis. *1986–87 survey of selected firms in the commercial hazardous waste management industry*. Washington, DC: U.S. Government Printing Office, March 31, 1988.

______ , Office of Pollution Prevention and Toxics. *1987–1993 toxics release inventory: CD-ROM*. Washington, DC: U.S. Government Printing Office, June 1995a.

______ , Office of Solid Waste and Emergency Response. *National biennial RCRA hazardous waste report (based on 1989 data)*, EPA530-R-992-027. Washington, DC: U.S. Government Printing Office, February 1993.

______ . *National capacity assessment report: Capacity planning pursuant to CERCLA Section 104(c)(9): Draft*, EPA530-R-94-040. Washington, DC: U.S. Government Printing Office, October, 1994.

______ . *National biennial RCRA hazardous waste report (based on 1993 data)*, EPA530-R-950-39A. Washington, DC: U.S. Government Printing Office, August 1995b.

Walters, Jonathan. "The Poisonous War over Hazardous Waste." *Governing*, November 1991, *5*(2), pp. 32–35.

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3. Alessio D'Amato, Alberto Iozzi, Giovanni Trovato. 2012. The trade of polyethylene waste: prices or policies?. *Environmental Economics and Policy Studies* . [CrossRef]
4. Derek Kellenberg. 2012. Trading wastes. *Journal of Environmental Economics and Management* **64**, 68-87. [CrossRef]
5. Takayoshi Shinkuma, Shunsuke Managi. 2011. Effectiveness of policy against illegal disposal of waste. *Environmental Economics and Policy Studies* . [CrossRef]
6. Andrea M. Leiter, Arno Parolini, Hannes Winner. 2011. Environmental regulation and investment: Evidence from European industry data. *Ecological Economics* **70**:4, 759-770. [CrossRef]
7. L. Tole, G. Koop. 2011. Do environmental regulations affect the location decisions of multinational gold mining firms?. *Journal of Economic Geography* **11**:1, 151-177. [CrossRef]
8. J. Ederington. 2010. Should Trade Agreements Include Environmental Policy?. *Review of Environmental Economics and Policy* **4**:1, 84-102. [CrossRef]
9. Hilary Sigman, Sarah Stafford. 2010. Management of Hazardous Waste and Contaminated Land. *Annual Review of Resource Economics* **3**:1, 110301102409075. [CrossRef]
10. Jen Baggs. 2009. International Trade in Hazardous Waste. *Review of International Economics* **17**:1, 1-16. [CrossRef]
11. CHAD P. BOWN, JOEL P. TRACHTMAN. 2009. Brazil – Measures Affecting Imports of Retreaded Tyres: A Balancing Act. *World Trade Review* **8**:01, 85. [CrossRef]
12. Anna Alberini, Shelby Frost. 2007. Forcing Firms to Think About the Future: Economic Incentives and the Fate of Hazardous Waste. *Environmental and Resource Economics* **36**:4, 451-474. [CrossRef]
13. Richard Benjamin, Jeffrey Wagner. 2006. Reconsidering the law and economics of low-level radioactive waste management. *Environmental Economics and Policy Studies* **8**, 33-53. [CrossRef]
14. P CHINTRAKARN, D MILLIMET. 2006. The environmental consequences of trade: Evidence from subnational trade flows. *Journal of Environmental Economics and Management* **52**:1, 430-453. [CrossRef]
15. Jeffrey A. Frankel, Andrew K. Rose. 2005. Is Trade Good or Bad for the Environment? Sorting Out the Causality. *Review of Economics and Statistics* **87**:1, 85-91. [CrossRef]
16. Michael RauscherChapter 27 International Trade, Foreign Investment, and the Environment 1403-1456. [CrossRef]
17. Brian R. Copeland, M. Scott Taylor. 2004. Trade, Growth, and the Environment. *Journal of Economic Literature* **42**:1, 7-71. [Abstract] [View PDF article] [PDF with links]
18. E Helland. 2003. Pollution incidence and political jurisdiction: evidence from the TRI. *Journal of Environmental Economics and Management* **46**:3, 403-424. [CrossRef]
19. C MCAUSLAND. 2002. Cross-Hauling of Polluting Factors. *Journal of Environmental Economics and Management* **44**:3, 448-470. [CrossRef]
20. P Fredriksson. 2002. Strategic Interaction and the Determination of Environmental Policy across U.S. States. *Journal of Urban Economics* **51**:1, 101-122. [CrossRef]