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FISCAL DECENTRALIZATION AND LAND POLICIES

Edited by Gregory K. Ingram and Yu-Hung Hong

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Decentralization and Environmental Decision Making

Shelby Gerking

A large share of responsibility for environmental policy in the United States rests with the federal government, due largely to two long-standing and widely held reservations about the ability of state and local governments to effectively carry out this function. The first reservation is that state and local officials may be too lax in setting environmental regulations if pollution generated in their jurisdiction is exported to another. The second is that even if exportation of pollution does not occur, local officials still may pay too little attention to environmental quality if they compete with one another in a "race to the bottom" to attract capital (Break 1967; Cumberland 1980). Revesz (2001), however, persuasively debunks general environmental policy prescriptions in favor of federal intervention. In addition, Oates (2002, 8) contends that more empirical work is needed to estimate the magnitude of distortions that would arise if state and local governments exercised more authority over environmental policy.

Oates and Schwab (1988) present a benchmark case against which to assess possible distortions that might arise if responsibility for environmental policy is shifted from the federal government to state and local governments. They demonstrate that a "race to the bottom" will not occur if several conditions are met, including that local jurisdictions have access to a full range of tax and regulatory

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instruments and that the economy is competitive, with no externalities (for further discussion, see Levinson [1997]). Because these conditions will not always hold, a vast theoretical literature has developed to explore implications of departures from this pure case (for surveys, see Wellisch [2000] and Wilson [1996, 1999]). The magnitude of distortions identified in these papers rests on two interrelated issues: (1) the extent to which state and local governments would set environmental stringency at a different level than would the federal government; and (2) the extent to which firms respond to changes in stringency of environmental regulation. If federal responsibility for the environment is decentralized to state and local governments and those governments set the same level of stringency as the federal government (e.g., the Oates and Schwab pure case), distortions do not arise. Correspondingly, if federal responsibilities for the environment are reassigned to state and local governments and firms do not alter their behavior in the face of changes in environmental regulations, no distortions arise.

Empirical studies of these issues differ greatly both in approach and in their findings. One branch of the literature attempts to treat both issues at once. For example, Bulte, List, and Strazicich (2007), Fredriksson and Millimet (2002), Goklany (1999), and List and Gerking (2000) consider specific situations in which states had an opportunity to play a leadership role in establishing environmental policy and find little evidence that environmental quality suffered. Another set of studies looks at how firms respond to changes in environmental policy. Recent studies of federal clean air regulations that divide the United States into attainment and nonattainment areas (e.g., Becker and Henderson 2000; Greenstone 2002) find that firms either relocate or shift production and pollution to areas where regulations are less strict, whereas earlier studies, surveyed by Jaffe et al. (1995), suggest little evidence of these effects.

The aim in this chapter is to analyze implications of further decentralizing environmental policy in a situation in which exportation of pollution to other jurisdictions is of possible importance. The focus is on the particular case previously considered by Sigman (1996) of generation and disposal of chlorinated solvent waste, a group of toxic chemicals that can be shipped across state boundaries. This case is worth a further look for three reasons. First, generation of toxic waste is likely to be relatively more sensitive to changes in regulatory policy than plant relocation decisions, so firm responses may be easier to identify. Second, Sigman's study as well as studies of toxic waste imports by Levinson (1999a, 1999b) found that firms are quite sensitive to changes in disposal taxes imposed by state governments. Consequently, these studies suggest that distortions may arise if further decentralization of toxic waste regulation from the federal government to state and local governments would result in less stringent controls. Third, the Sigman and Levinson studies covered only the early years of the Toxic Release Inventory (TRI) program. (For a description of this program, see Hamilton [2005].) Thus, it will be of interest to determine if these results hold after updating the analysis to the most recent years for which data are available.

In the remainder of this chapter, estimation of firms' responses to hazardous waste taxes is motivated by a simple model proposed by Levinson (1999a) to compare the marginal social cost of toxic waste disposal with the marginal private cost of disposing of this waste, inclusive of state taxes. The disparity between these costs is determined by the interaction of (1) the fraction of the waste shipped out of state; and (2) the elasticity of waste generation (or waste disposal) with respect to disposal costs. This elasticity is estimated using data assembled for the period from 1988 to 2004 on plant-level generation and disposal of chlorinated solvent waste and state taxes on hazardous waste disposal.

Two main results emerge from the empirical analysis. First, when analyzing the data over the entire 1988 to 2004 time period, generation and disposal of chlorinated solvent wastes do not respond to changes in disposal costs occasioned by changes in state tax rates. By 2004, however, disposal of these chemicals had decreased dramatically due to technical changes that permitted increased use of aqueous metal cleaners and greater reuse and recycling of chemical cleaners. These technical changes may well have reduced firms' responsiveness to waste disposal taxes, thus making it difficult to conclude that distortions arising from decentralization of environmental policy are likely to be small. Second, during the early years of the TRI program (1988 to 1990) and prior to the time these technical changes occurred, generation and disposal of chlorinated solvent waste did not respond to changes in disposal tax rates. This outcome reverses Sigman's (1996) findings and strengthens the conclusion that no efficiency consequences arise from assigning greater responsibility for regulating chlorinated solvent waste to the states.

Model

Levinson (1999a) developed a model to show how distortions can arise in toxic waste disposal because of the interaction between waste exportation and the elasticity of firms' waste disposal practices with respect to disposal costs. The model envisions M jurisdictions. Each jurisdiction has a fixed amount of industrial activity that produces hazardous waste. Waste is unsightly or poses a health hazard to the identical residents of each jurisdiction; thus, it is a public bad.

Each jurisdiction has two available options to reduce residents' exposure to waste. First, although it is costly to transport waste, waste can be shipped to another jurisdiction, where it becomes somebody else's problem. Second, jurisdiction officials can tax disposal of waste in their own jurisdiction. The disposal tax rate is differentiated according to whether the waste is locally generated or is shipped from another jurisdiction. In several court cases, discriminatory taxation of waste disposed of in one state but generated in another has been found to violate the commerce clause of the United States Constitution (see Urie 1995). Nonetheless, states can (and do) to some extent follow the "not-in-my-back-yard" (NIMBY) principle by less direct means, such as taxing the disposal of waste on the generating plant's site at one rate and taxing off-site disposal at another (higher) rate.

Residents of each jurisdiction get utility from consuming the composite good y and get disutility from disposal of waste in their jurisdiction (W). Thus, the utility of each resident in each jurisdiction is

$$(1) \qquad U = U(y, W).$$

In equation (1), $W = W_D + W_I$, where W_D and W_I denote, respectively, local or domestic waste disposed of locally and waste imports generated outside the jurisdiction but disposed of locally. Each resident of each jurisdiction receives a pro rata share of profits from local industrial production (π) and tax revenue generated by waste disposal. Thus, the budget constraint is

$$(2) \qquad y = \frac{1}{n}(\pi - qW) + \frac{1}{n}(\tau_D W_D + \tau_I W_I),$$

where the price of y is normalized to unity, n is the number of residents in the jurisdiction, q is private waste disposal costs (assumed to be the same for the two types of waste), and τ_j, $j = D, I$ is the sum of per unit private waste disposal costs plus the tax rates on disposal for the two types of waste. Costs of transportation on imported waste from other jurisdictions are ignored, and private waste disposal costs are treated as exogenous.

Local firms produce the consumption good (y), purchase competitively supplied inputs, generate waste (g), and maximize profits. Firms take as exogenous waste disposal taxes in other jurisdictions as well as prices and quantities of inputs other than waste. Let f denote the production function. Local profits are then given by

$$(3) \qquad \pi = f(g) - \tau_j g,$$

where τ_j, $j = D, E$ is the per unit cost of disposing of local waste locally and the per unit cost of exporting local waste to another jurisdiction for disposal and other variables are as defined in equation (2). To maximize profits, each firm disposes of waste at least cost. Therefore, if all waste is homogeneous, if jurisdictions are treated as points in space, and if the cost of transporting waste is a constant multiple of distance, firms either will dispose of all waste locally ($g = W_D$) or will ship all waste for disposal in another jurisdiction. On the other hand, as discussed more fully by Levinson (1999a), if waste produced by different firms is heterogeneous and possibly subject to different transportation charges, a fraction of it may be disposed of locally (W_D / g), and the remainder would be shipped to another jurisdiction.

Jurisdiction officials choose τ_D and τ_I by setting tax rates so as to maximize their constituents' utility subject to the budget constraint in equation (2) while accounting for profit maximization by firms as in equation (3). The optimal choice of disposal costs for imported waste from other jurisdictions can be found by solving

$$(4) \qquad -n\left[\frac{\partial U/\partial W}{\partial U/\partial y}\right]\frac{\partial W_I}{\partial \tau_I} = W_I + \tau_I \frac{\partial W_I}{\partial \tau_I}.$$

Thus,

$$(5) \qquad \tau_I^* = K\left[\frac{\eta_I - 1}{\eta_I}\right]^{-1},$$

where K is the population of the jurisdiction multiplied by the negative of the marginal disutility of waste divided by the marginal utility of income and η_I is the absolute value of the elasticity of waste imports to the jurisdiction with respect to a change in disposal costs τ_I. In addition, $K = -n(\partial U / \partial W) / (\partial U / \partial y)]$ is interpreted as the marginal social cost of waste disposal. Equation (5) shows that local officials will behave as a single-price monopolist, operating on the elastic part of the demand curve for waste disposal by waste generators in other jurisdictions. Thus, the disposal price per unit of waste paid by nonresidents will exceed the marginal social cost of waste disposal; that is, $\tau_I^* / K > 1$. Also, the ratio τ_I^* / K is inversely related to η_I, so if η_I increases, more waste is deterred from entering the jurisdiction by a given increase in τ_I, and as η_I grows without bound, the value of τ_I^* / K will tend toward unity.

Correspondingly, the optimal tax inclusive cost to dispose of locally generated waste can be found by solving for τ_D from

$$(6) \qquad \frac{\partial f}{\partial g}\frac{\partial g}{\partial \tau_D} = K\frac{\partial W_D}{\partial \tau_D},$$

where $\partial f / \partial g = \tau_D$. Thus, denoting the absolute value of the elasticity of local waste disposal with respect to the local tax rate as η_D, the optimal cost to dispose of locally generated waste is

$$(7) \qquad \tau_D^* = K\left[1 - \frac{1-(g/W_D)}{\eta_D}\right]^{-1}.$$

In the case in which all local waste is disposed of locally ($g = W_D$), the cost of local disposal of local waste is set equal to marginal social cost ($\tau_D^* = K$). Thus, in this model, if pollution is not exported, no distortions arise and $K / \tau_D^* = 1$ regardless of the value of η_D. In the case in which waste is heterogeneous (i.e., $W_D < g$), the jurisdiction will inefficiently set the cost of local disposal below marginal social cost. Therefore, $\tau_D^* < K$ and $\tau_D^* \leq K \leq \tau_I^*$.

To better appreciate the relationship between the private cost of disposing of local waste locally and the marginal social cost of waste disposal, consider how the magnitude of the ratio K / τ_D^* varies with g / W_D and η_D. A useful starting point is the case in which $\eta_D = 1$. In this situation, equation (7) can be rewritten as $K / \tau_D^* = g / W_D$, indicating that the ratio of the marginal social cost of disposal to the optimal local private disposal equates to the reciprocal of the fraction of waste that is exported. If a jurisdiction can export more of its own pollution, it will have a lower incentive to control it. In addition, if the waste is entirely exported ($W_D = 0$), then K / τ_D^* becomes arbitrarily large regardless of the value of η_D and waste might be better controlled by a higher level of government.

Furthermore, for a given value of g / W_D, the magnitude of K / τ_D^* is inversely related to the value of η_D: the value of K / τ_D^* is smaller if $\eta_D > 1$ than if $\eta_D < 1$. In the extreme case in which the elasticity of waste disposal with respect to cost approaches infinity, K / τ_D^* approaches unity, but a small deviation of τ_D^* from K has a comparatively large effect on production of waste. In the other extreme case in which $\eta_D = 0$, firms do not alter the amount of waste generated in the face of tax changes and the ratio K / τ_D^* is arbitrarily large. In that situation, a marginal increase in the jurisdiction's tax rate not only does not distort choices made by firms as to the amount of waste to generate, but it also has no effect on income of the jurisdiction's residents. Increased tax revenue redistributed to residents would be exactly offset by reduced distributions of profits. Waste reduction would instead have to be achieved using policy instruments not directly considered in the model, such as a sufficiently large tax increase, so that firms would earn less than normal profits at all possible output levels.

Prior Estimates

Several studies present evidence on the behavior of firms and environmental policy makers when transboundary pollution is at issue. Results of selected studies are briefly summarized here. Alberini and Bartholomew (1999) and Alberini and Frost (2007), for example, find that firms generating spent chlorinated solvent waste are sensitive to potential future liability costs that can arise if the disposal facility used becomes a Superfund site. Other studies (reviewed below) identify evidence, in both U.S. and international contexts, that pollution control is less stringent when a portion of the pollution is exported to other jurisdictions. Three studies, described in greater detail at the end of this section, develop estimates that can be used to compute values of τ_I^* / K and K / τ_D^*.

Seven studies, summarized in table 7.1, consider the possibility that regulators are too lax in setting environmental policy for pollutants that are likely to cross jurisdictional boundaries in the United States. Four of these studies (Gray and Shadbegian 2004; Helland and Whitford 2003; Novello 1992; Sigman 1996) deal with pollution within the United States; the remaining three studies (Levinson 1999a, 1999b; Sigman 1996) are discussed in more detail later on. Novello (1992) finds that regulatory stringency weakens when local emissions of volatile organic compounds and nitrogen oxides affect ozone levels in downwind states. Sigman (2005) looks at how states set water quality standards for rivers if they are authorized to assume responsibility for implementation and

Table 7.1
Studies of Pollution Exportation in the United States

Author and Date	Nature of Study	Results
Novello (1992)	Interstate transmission of air emissions	Regulatory stringency weakens when air emissions are exported to downwind states.
Sigman (2005)	Effects of state involvement in setting water quality standards for rivers	Some states allowed water quality to degrade by about 4%, with environmental costs to downstream states of about $17 million.
Gray and Shadbegian (2004)	Environmental regulation of pulp and paper mills	Plants whose pollution affects residents of other states generally have higher emissions.
Helland and Whitford (2003)	Econometric analysis of Toxic Release Inventory data	Facilities' emissions were found to be systematically higher when located in counties that border other states.
Levinson (1999a, 1999b)	Estimates of response to hazardous waste imports to hazardous waste import taxes	Interstate hazardous waste shipments were found to be negatively related to the tax rate on hazardous waste.
Sigman (1996)	Estimates of responsiveness of chlorinated solvent waste generation to hazardous waste disposal taxes	Generation of chlorinated solvent waste is strongly negatively related to waste disposal taxes.

enforcement of U.S. Clean Water Act regulations and if a portion of discharges will end up in downstream states. Sigman's analysis indicates that states in this situation allow water quality to degrade by about 4 percent, with a comparatively small environmental cost to downstream states of $17 million. Gray and Shadbegian (2004), in their study of environmental regulation of pulp and paper mills, find that plants whose pollution affects residents of other states generally have higher emissions than plants whose pollution affects only their home state. Helland and Whitford (2003) cite court cases in which the plaintiff alleges more lenient treatment of polluters when the incidence of pollution falls outside the jurisdiction and then present econometric evidence based on data from the TRI demonstrating that facilities' emissions are systematically higher in counties that border other states than in counties that are within the home state.

Among studies conducted in an international context (see summary in table 7.2), Sigman (2002) shows that countries protect less vigorously against effluent discharges into rivers that transport perhaps one-third of them to other countries downstream, a finding that is consistent with her work on the Clean Water Act

Table 7.2
Studies of Pollution Exportation in an International Context

Author and Date	Nature of Study	Results
Sigman (2002)	Analysis of effluent discharges into rivers that cross international boundaries	Countries protect less vigorously against such discharges.
Murdoch and Sandler (1997a, 1997b)	Inefficiently low taxes on chlorofluorocarbon emissions providing an incentive for international cooperation	Incentives to cut back on emissions rise with national income, as implied by the theory.
Murdoch, Sandler, and Sargent (1997)	Incentives for international cooperation to control air emissions of sulfur and nitrogen oxides among European countries	Theoretical model developed leads to an empirical representation that yields reasonable results for sulfur but less satisfying results for nitrogen oxides.
Davies and Naughton (2006)	Gains from international cooperation arising from cross-border pollution spillovers	Support for this idea was found by analyzing data on treaty participation.

cited above. Murdoch and Sandler (1997a, 1997b) consider the idea that inefficiently low taxes and regulations on pollution (chlorofluorocarbon emissions in this case) provide an incentive for international cooperation. Murdoch, Sandler, and Sargent (1997) also look into this issue in their study of European sulfur and nitrogen oxide air emissions. Davies and Naughton (2006) extend the model developed in the previous section by permitting firms subject to environmental taxes to relocate in other countries with weaker environmental regulations. They show that greater cross-border spillovers increase gains from cooperation and find support for this hypothesis using data on treaty participation.

Levinson (1999a, 1999b) (for a summary, see table 7.1) estimates the responsiveness of waste imports to waste import taxes (η_I) by focusing on interstate shipments of hazardous waste from 1989 to 1995. In 1991, for example, approximately 10 percent of all hazardous waste generated in the United States was shipped across state boundaries. Data on hazardous waste shipments are taken from the TRI, and data on tax rates that states apply to hazardous waste imports are compiled from *Tax Day*, a Commerce Clearinghouse publication. Also considered is that during the late 1980s and early 1990s, many states levied higher taxes on waste imports than on locally generated waste, despite a series of Supreme Court rulings that discriminatory tax treatment of interstate waste imports represents an unconstitutional violation of the Commerce Clause. A key finding from the empirical analysis is that interstate hazardous waste shipments for disposal is negatively related to the tax rate applied to imported waste. This outcome suggests that higher taxes deter interstate shipments of hazardous waste.

Estimates of the elasticity of waste imports with respect to waste import taxes are between 0.09 and 0.13. As Levinson (1999a) argues, these tax elasticities are considerable, given that taxes are only a part (less than 10 percent) of overall disposal costs, and suggest that waste disposal taxes in different states are close substitutes. Estimates of η_I can be obtained from these tax elasticities by redefining the tax base as the sum of private disposal costs (estimated to be approximately \$156 per ton in 1993) plus applicable taxes on imported waste (which averaged about \$15 per ton across the 48 contiguous states, including those with a zero tax rate). These estimates, which range from 1.06 to 1.45, are consistent with the notion that states behave as single-price monopolists in setting local disposal costs and imply that local officials set charges to dispose of imported waste at between 3 and 12 times marginal social cost; see equation (5).

Estimates of η_I would be larger and estimates of τ_I^* / K would be correspondingly smaller, however, had transportation costs (ignored in the model) been factored into the calculations. Assuming that transportation costs were \$0.25 per ton-mile in the early 1990s and that the average length of an interstate trip was 300 miles (Deyle and Bretschneider 1995), private disposal costs per ton would increase by 48 percent, to \$231 (= \$156 + \$75). After accounting for these additional costs, estimates of η_I corresponding to those presented by Levinson (1999a) would range from 1.47 to 2.13. Values of τ_I^* / K would decline to a range of 1.88 to 3.13.

Instead of looking at how interstate shipments of waste respond to discriminatory taxation, Sigman (1996) considers the response of local waste generation to local disposal costs for the case of spent chlorinated solvents used in metal parts cleaning (for a summary, see table 7.1). Her work builds on earlier studies (Deyle and Bretschneider 1995; USEPA 1984; Wolf and Camm 1987) that differed considerably in their findings on the sensitivity of waste generation to waste management costs. Sigman regressed plant-level data on chlorinated solvent waste generation from the TRI on tax-inclusive costs of disposing of these chemicals and other variables for the period 1987 to 1990. To focus on metal cleaning applications, data were drawn from 31 states that imposed either land disposal or incineration taxes on waste generation and from facilities in six manufacturing sectors. Disposal of chlorinated solvents was achieved mainly by incineration, so cost data were developed by adding U.S. government estimates of incineration costs to state taxes on incineration of in-state wastes.

This cost variable, however, exhibits little variation over time for a given state, so use of fixed-effects estimation (see table IV in Sigman [1996, 209]), which uses only within-plant information, is likely to lead to fragile estimates of η_D. Because the estimate of private incineration costs is assumed to be the same for all states, the tax rate represents the only source of variation in the cost variable used in the regression model. In addition, 20 of the 31 states did not change their incineration tax rate over the 1987 to 1990 period, and 7 of the remaining 11 states changed this tax rate only once. The extent to which lack of variation in the cost variable might result in fragile estimates of η_D is investigated in the next section.

In any case, a key finding is that chlorinated solvent waste generation is quite sensitive to tax-inclusive costs of disposal; for example, Sigman's table IV and accompanying discussion (Sigman 1996, 210) show that when out-of-state tax rates, plant effects, and time effects are controlled, η_D is estimated to be 7.83. This value is at the low end of corresponding elasticities estimated in several equations using other methods (at the high end is $\eta_D = 22$). In addition, Sigman states (p. 207) that "49% of the [chlorinated solvent] waste was managed in the state where it was generated." Thus, $g / W_D = 2.04$, and the estimate of $\eta_D = 7.83$ implies that $K / \tau_D^* = 1.133$. This calculation illustrates that the relatively high estimated sensitivity of chlorinated solvent disposal to changes in disposal costs combined with the relatively large percentage of these wastes shipped out of state means that the marginal social cost of this activity is more than 13 percent higher than the price paid by waste generators.

State taxes represent only about 2 percent of total disposal costs. In 1987 state taxes on incineration (a relatively expensive disposal option) averaged \$12 per ton, whereas spent chlorinated solvent disposal costs were estimated to be \$659 per ton. Thus, Sigman (1996) estimates that elimination of state taxes would stimulate production of chlorinated solvent waste by only 5 percent to 12 percent. Nonetheless, because of a relatively low ratio of state taxes to total disposal costs, average incineration taxes would have to be increased by about \$86 per ton, or by a factor of 7.17 (= 86/12), to bring K into equality with τ_D. Although such a large percentage increase in disposal taxes is perhaps politically infeasible, the estimate $\eta_D = 7.83$ suggests the implausible result that a 13 percent increase in total disposal costs would roughly eliminate the generation of chlorinated solvent waste.

New Estimates

There are new estimates of the response of spent chlorinated solvent waste generation to state taxation of this activity. Waste of this type arises from cleaning metal parts using tetrachloroethylene (perchloroethylene), trichloroethylene, 1,1,1-trichloroethane, or dichloromethane (methylene chloride). With the exception of trichloroethane, these chemicals are regarded as either possible or probable human carcinogens (USEPA 2005). Data on industrial disposal of these chemicals are taken from the TRI for the period 1988 to 2004. Thus, they extend the time period considered in the earlier study (1987 to 1990) by 14 years, which, in turn, allows for more possible changes in disposal tax rates levied by each state.

Table 7.3 shows that between 1988 and 2004, industrial disposal of all four chemicals declined sharply, from 421.11 million pounds in 1988 to 289.55 million pounds in 1991 to 16.75 million pounds in 2004. Thus, the quantity of these chemicals disposed of in 2004 represents only 4 percent of the quantity disposed of in 1988. Introduction of effective aqueous cleaners has resulted in a substitution away from use of chlorinated solvents in many applications; in applications in which they are still used, increased recycling and reuse has further lowered

Table 7.3
Trends in Industrial Disposal of Chlorinated Solvents (in millions of pounds)

Chemical	1988		1991		2004	
	Off-Site	Total	Off-Site	Total	Off-Site	Total
Tetrachlororethylene	1.39	37.72	0.12	17.65	0.14	2.47
Trichloroethylene	1.47	57.45	0.12	36.55	0.07	6.34
1,1,1-Trichloroethane	5.95	187.02	1.01	149.15	0.01	0.08
Dichloromethane	7.81	138.92	0.50	86.20	0.23	7.86
Total	16.62	421.11	1.75	289.55	0.45	16.75

Source: Data taken from the U.S. Environmental Protection Agency Toxic Release Inventory Explorer, http://www.usepa.gov/triexplorer.

quantities disposed. Table 7.3 also indicates that all four chemicals are mainly disposed of on the site where they were generated; the fraction of spent chlorinated solvents disposed of off-site was 3.9 percent (16.62/421.11) in 1988 and 2.6 percent (0.45/16.75) in 2004. These estimates, computed directly from TRI data, show that out-of-state disposal of chlorinated solvent waste is a much less frequent occurrence than assumed by Sigman.

The next step is to analyze data on disposal of the four chemicals listed in table 7.3 by plant and over time. All plants are involved in manufacturing and are classified in six specific manufacturing sectors to maintain consistency with Sigman (1996) and to focus on sectors in which the four chemicals would be used for cleaning metal parts. These data form an unbalanced panel because plants do not appear in the inventory in years when releases are below minimum reporting thresholds. In any case, 37,397 observations are available from 8,030 different plants, representing 46 of the contiguous 48 states. Plants from Arkansas and Maryland do not appear in the data set because of difficulties determining their waste disposal tax rates. The average is 4.66 observations available per plant.

For each plant in each year, the main data elements consist of total production-related chlorinated solvent waste generated and total quantity of this type of waste that was disposed of either on-site or off-site. The former measure is referred to as "waste generated," and the latter measure is referred to as "waste disposal." Waste disposal figures generally are lower than figures for waste generated because spent chlorinated solvents can be recycled or used as fuel. The plant-level data do not break down quantities of waste disposed of on-site versus off-site; thus, it is not possible to distinguish intrastate from interstate waste shipments.

Table 7.4 presents means of chlorinated solvent waste generated and waste disposed for all plants in the data set for selected years. These tabulations indicate that after 1991, the number of chlorinated solvent waste generators declined over time, whereas waste generation per plant increased. Apparently, many plants that in the early 1990s generated relatively small quantities of this type of waste

Table 7.4
Chlorinated Solvent Waste Generated and Disposed: Means of Sample Plants for Selected Years

Year	Chlorinated Solvent Waste Generated (in tons)	Chlorinated Solvent Waste Disposed (in tons)	Number of Plants
1988	37.84	35.46	3,288
1991	87.69	24.98	5,006
1995	110.01	7.89	2,210
2000	229.80	18.28	1,080
2004	270.99	9.09	718

now fall below the reporting threshold. In addition, the ratio of waste disposed to waste generated has fallen over time, indicating the increased importance of reuse, recycling, and use of these chemicals as fuels.

Data on tax rates applicable to the disposal of spent chlorinated solvent waste were assembled in two stages. First, Levinson's data on on-site and off-site disposal tax rates per ton of waste by state and year were obtained for the period 1988 to 1995. These data, obtained from *Tax Day*, are fully described in his two previously referenced papers (Levinson 1999a, 1999b). Second, these tax data were brought forward to the year 2004 by a LexisNexis search of each state's statutes. This search was conducted by first verifying the Levinson data for the years 1991 to 1995 and then extending these data forward to 2004. The year 1991 was the earliest year for which a LexisNexis search of state statutes could be performed. Disposal tax rate data obtained in the search for the period 1991 to 1995 are virtually identical with those used by Levinson, but the Levinson data for 1988 to 1990 lack complete agreement with the incineration tax data reported by Sigman (1996).

The LexisNexis search underscored a number of differences between states in the tax treatment of the production and disposal of toxic waste. In some states (e.g., Alabama), several separate waste disposal taxes are levied on a common base to earmark the resulting revenue streams for different purposes. Thus, it was necessary to identify and then add each of these individual taxes together to obtain the total tax rate that would be seen by waste generators. In other states (e.g., Georgia), taxes are levied not only on toxic waste disposal, but also on recycling of waste and use of waste as a fuel. Illinois and Kentucky tax disposal of waste by volume, rather than by weight; tax rates for these states were converted from cents per gallon to dollars per ton using the number of gallons in a ton of water. New York and Maine impose graduated waste disposal tax rates, and a weighted average of these rates was computed to obtain a single tax rate faced by the "average" waste generator.

Table 7.5
Average On-Site and Off-Site Disposal Tax Rates, Selected Years

Year	On-Site Disposal Tax Rate (per ton)	Number of States Levying This Tax	Off-Site Disposal Tax Rate (per ton)	Number of States Levying This Tax
1988	$13.18	18	$18.50	21
1991	$17.82	23	$26.58	26
1995	$18.59	26	$23.24	31
2000	$22.70	29	$47.02	33
2004	$22.78	29	$47.14	33

Table 7.5 shows trends in on-site and off-site disposal tax rates for selected years. Figures presented are unweighted averages of state tax rates for all states that levy these taxes. As indicated, more states levy taxes on off-site disposal than on on-site disposal, and, as predicted by the model, off-site disposal tends to be taxed at higher rates than on-site disposal. Also, the number of states imposing these types of taxes increased over the years; tax rates on both types of disposal have risen as well. As indicated above, tax rates from 1988 to 1995 were compiled by Levinson. Off-site tax rates for these years include any discriminatory taxes applied to interstate shipments of waste. The decline in average off-site tax rates between 1991 and 1995 is probably due to the decline in the importance of discriminatory taxation of these interstate shipments following unfavorable Supreme Court rulings. The increase in average off-site disposal tax rates between 1995 and 2000 is due to comparatively large increases in these rates by two states, Kansas and Oregon.

Further analysis of the tax rate data indicates that over the period 1988 to 2004, on-site disposal tax rates (used in the analysis below) changed an average of 1.71 times in each state. California changed its on-site disposal tax rate eight times over this period, Utah and Louisiana changed their on-site disposal tax rates six times; and most other states changed their tax rates one to three times. Several states, including Massachusetts and New Jersey, did not levy an on-site disposal tax at any time between 1988 and 2004. In all, 14 states left their tax rates unchanged for the entire period, including those that did not levy such a tax. Most of the on-site disposal tax rate changes occurred before 1995; lengthening the time period examined beyond 1990 is nonetheless useful in contributing additional within-state and thus within-plant variation to the disposal cost variable.

Effects of changes in tax rates on chlorinated solvent waste disposal and generation are presented in table 7.6. In each regression, the unit of observation is a plant in a given year. Waste disposal tax rates are matched to plants according to the state in which they are located and the year in which they were observed.

Table 7.6
Estimates of Elasticity of Chlorinated Solvent Waste Generation and Disposal with Respect to On-Site Disposal Costs, 1988–2004

Dependent Variable	Disposal	Disposal	Disposal	Generation
Explanatory variable	(1)	(2)	(3)	(4)
Natural logarithm of	–1.811[a]	–0.301	0.956	–0.604
on-site disposal costs	(0.040)	(0.648)	(0.625)	(0.593)
Constant	21.247	[b]	3.219	14.048
	(2.618)		(4.069)	(3.862)
N	34,717	34,717	34,717	35,675
R^2	0.0006	0.811	0.831	0.819
Plant effects	No	Yes	Yes	Yes
Time effects	No	No	Yes	Yes

Note: Standard errors are given in parentheses beneath the coefficient estimates.
[a]Denotes significance at the 1% level.
[b]Denotes omitted variable.

Plants are assumed to take waste disposal tax rates as exogenous. Levinson (1999a, 1999b) bases his analysis on the possible endogeneity of state tax rates (the idea that states that receive a lot of waste respond by enacting high taxes); his analysis, however, was at the state level rather than at the plant level. Waste disposal is the dependent variable of primary interest because it is the quantity of waste produced that is subject to taxation. Sigman (1996) used waste generation as the dependent variable in her study, so this variable is analyzed here as well. Values of waste generation and waste disposal might be used interchangeably for many plants in the early years of the sample, but, as indicated in table 7.4, the ratio of waste disposal to waste generation declines substantially with the passage of time. Both waste disposal and waste generation are measured in natural logarithms after eliminating the plant and year observations for which these variables are zero (2,680 observations in the case of waste disposal and 1,722 observations in the case of waste generation).

Because inclusion of plant effects and year effects (see below) control for many other factors, including plant-specific factors, that might be expected to affect waste disposal, the only explanatory variable in all regressions is the natural logarithm of the on-site cost of disposing of chlorinated solvent waste. As in Sigman (1996), the cost measure was computed as private disposal cost ($659) plus the on-site disposal tax rate for states that levy such a tax. The on-site tax rate rather than the off-site tax rate is used here because, as indicated above, the overwhelming percentage of chlorinated solvent waste is disposed of on-site.

The tax rate is the only source of variation in the disposal cost measure; thus, this variable does not change for plants located in states that did not levy an on-site disposal tax or did not change the disposal tax over the sample period. A distance-weighted average of other states' disposal tax rates is not included because it appears that out-of-state shipments often go to states with specialized disposal facilities rather than to neighboring states.

In the table 7.6 column (1) regression, in which the dependent variable is chlorinated solvent waste disposal, estimation is by ordinary least squares. The column (2) regression adds plant fixed effects to control unobserved heterogeneity across plants. Plant effects fully account for differences in plant size, plant location, plant output, management compliance with TRI reporting, and other factors that vary across plants, but not over time. The column (3) regression adds time effects to the regression of waste disposal on disposal costs. Time effects control factors that affect all plants but that change over time, such as changes in federal regulatory policy toward production and disposal of toxic chemicals and innovations that promote alternative and less hazardous cleaning methods. Hausman tests reject random-effects estimates in favor of fixed-effects estimates in the specifications shown in columns (2) through (4).

In the table 7.6 column (1) regression, based on 34,717 observations, the estimate of the elasticity of waste disposal with respect to disposal costs is –1.811. This estimate is significantly different from zero at the 1 percent level, although $R^2 = 0.0006$ for this regression. As indicated in column (2), $R^2 = 0.811$ once the 7,661 plant effects are added. The column (2) estimate of the elasticity remains negative, but it is not significantly different from zero at conventional levels. Controlling for unobserved heterogeneity among plants reduces both the magnitude and significance of the elasticity of waste generation with respect to cost. When time effects are added in column (3), this elasticity estimate turns positive and is not significantly different from zero at conventional levels.

In column (4), the dependent variable is the natural logarithm of chlorinated solvent waste generation. This regression, based on 35,675 observations, has $R^2 = 0.819$. Estimates indicate that the elasticity of waste generation with respect to cost is negative, but not significantly different from zero at conventional levels after controlling for both plant and time effects. This estimate implies much less sensitivity of waste generation to disposal taxes than do the results of Sigman (1996), but is nonetheless consistent with estimates presented in columns (2) and (3) that control for plant effects and time effects.

The column (1) estimate of the elasticity of waste disposal with respect to cost, although it was not conditioned on plant effects and time effects, can be used to obtain an illustrative estimate of K / τ_D^* by assuming that all waste shipped off-site is shipped out of state. From table 7.6, using $\eta_D = 1.81$ from column (1) together with an estimate of $g / W_D = 1.027$ for 2004, yields $K / \tau_D^* = 1.015$. This estimate suggests that an on-site disposal tax rate increase of \$10.23 would be needed in the "average" state to bring marginal social cost and marginal private disposal costs into equality. In 2004 this dollar amount represented a 45 percent increase in the tax (see table 7.5), a 1.5 percent increase in disposal costs, and a 2.67 percent reduction in chlorinated solvent disposal. Because of the comparatively larger estimates of both the extent of out-of-state shipments and of $\eta_D = 7.83$, Sigman's 1996 results, described previously, show a much larger reduction in disposal for a smaller conjectured tax increase.

Estimates in table 7.7, columns (2) through (4), on the other hand, suggest that both generation and disposal of chlorinated solvent waste do not change in the face of changes in state tax rates, at least over the range of tax rates observed for the 1988 to 2004 period. This outcome implies that although taxes on waste disposal raise revenue, they do not distort choices of the quantity of waste disposed. Thus, the value of K / τ_D^* is arbitrarily large. Based on these estimates, state tax policies based on a desire to export pollution have been ineffective.

As mentioned earlier, an important qualification regarding these results is that the number of plants included in the data set becomes smaller with the passage of time partly because of technical changes in the disposal of chlorinated solvent waste. Over time, an increasing number of plants generate amounts of chlorinated solvent waste that fall below threshold values that trigger a re-

Table 7.7
Estimates of the Elasticity of Chlorinated Solvent Waste Generation and Disposal with Respect to Disposal Costs, 1988–1990

Dependent Variable	Disposal	Generation	Disposal	Generation	Disposal	Generation
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)
Natural logarithm of on-site disposal costs	1.594 (1.841)	1.406 (1.731)	[b]	[b]	[b]	[b]
Natural logarithm of disposal costs using incineration tax rate	[b]	[b]	–7.530[a] (3.132)	–9.699[a] (2.971)	–1.131 (3.318)	–2.198 (3.141)
Constant	–0.376 (11.988)	0.982 (11.275)	[b]	[b]	17.388 (21.563)	24.442 (20.411)
R^2	0.869	0.868	0.869	0.869	0.870	0.870
N	9,785	9,785	7,792	7,792	7,792	7,792
States	46	46	31	31	31	31
Plant effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	No	No	Yes	Yes

Note: Standard errors are given in parentheses beneath the coefficient estimates.
[a]Denotes significance at the 1% level.
[b]Denotes omitted variable.

porting requirement. Since 1989 these threshold values have been set at 25,000 pounds per year for a chemical manufactured or processed at a facility and 10,000 pounds per year for a chemical used at a facility (*Code of Federal Regulations* 2007). It would therefore be of interest not only to model the response of the larger generators to changes in tax treatment, but also to model attrition from the sample as many generators reduce their reliance on chlorinated solvents. Modeling attrition, however, may turn out to be challenging because some plants leave the data, only to return in subsequent years (see Greene 2003).

Nonetheless, conclusions drawn from the table 7.6 regressions are robust to a number of alterations in the specifications given in table 7.7. First, column (1) shows that when the waste disposal equation with plant and time effects is re-estimated using data from 1988 to 1990 to roughly coincide with the time period used in previous studies (Alberini and Frost 2007; Sigman 1996), the cost elasticity estimate does not differ significantly from zero. If the natural logarithm of waste generation is used as the dependent variable in the column (2) regression, the cost elasticity estimate also does not differ significantly from zero. In both of these regressions, this outcome is the same if the cost elasticity estimate is conditioned only on plant effects. In addition, the column (1) and column (2) results are not sensitive to whether the sample is restricted to plants on which a time series of six or more observations are available.

Second, columns (3) and (4) of table 7.7 show estimates of the cost elasticity of waste disposal and waste generation for the period 1988 to 1990 when (1) the cost variable is computed using the incineration tax rates taken from Sigman (1996, 201); (2) the sample is restricted to the 31 states for which incineration tax rates are available; and (3) cost elasticity estimates are conditioned only on plant effects. Outcomes of these regressions, similar to those reported by Sigman, show that cost elasticity estimates are large, negative, and significantly different from zero. As shown in columns (5) and (6), however, these one-way fixed-effects estimates are fragile, confirming the conjecture in the previous section. When time effects are added to both of these regressions, the cost elasticity estimate is no longer significantly different from zero at conventional levels. Therefore, when both plant effects and time effects are included in the regression, the elasticity of both waste disposal and waste generation with respect to costs is no different from zero, no matter which tax variable is used.

Thus, it appears that Sigman obtained different results from those presented in columns (1) and (2) of table 7.7 because (1) as noted earlier, her estimates of state waste disposal tax rates differed from those used here and in the Levinson studies; and (2) her findings are based on a one-way fixed-effects analysis in which only plant effects were included, rather than on the two-way fixed-effects analysis including both plant effects and time effects as described in her narrative (Sigman 1996, 210). Importantly, adding time effects—see columns (5) and (6)—to the regressions containing only plant effects—columns (3) and (4)—destroys the significance of the coefficient of the waste disposal tax variable.

Third, cost elasticity estimates, re-estimated for the entire 1988 to 2004 data set using a log-linear functional form rather than a log-log functional form, did not differ significantly from zero (results not shown). This outcome holds no matter whether the dependent variable measures waste generation or waste disposal. A linear specification was not tried because it implausibly suggests that a $1 tax change has the same absolute effect on waste generation and disposal for a small firm as for a large firm.

Conclusions

Many distortions appear when subnational governments have authority over aspects of environmental policy. Efficiency losses can arise when policies undertaken by these governments distort the behavior of firms by encouraging relocation or by encouraging emission of more than the optimal amount of pollution. Thus, in deciding whether to decentralize environmental decision making, it is helpful to have an idea of how large these distortions may be. After analyzing the response of firms that generate and dispose of chlorinated solvent waste to changes in state taxation, two main results emerge. First, generation and disposal of chlorinated solvent wastes do not respond to changes in disposal costs occasioned by changes in state tax rates between 1988 and 2004. Disposal of these chemicals decreased dramatically over this period, however, due to technical changes that permitted increased use of aqueous metal cleaners as well as greater reuse and recycling of chemical cleaners. These technical changes may well have reduced firms' responsiveness to waste disposal taxes, thus making it difficult to conclude that distortions arising from decentralization of environmental policy are likely to be small. Second, during the early years of the TRI program (1988 to 1990) and prior to these technical changes, generation and disposal of chlorinated solvent waste did not respond to changes in disposal tax rates. This outcome reverses Sigman's (1996) findings and serves to strengthen the conclusion that no efficiency consequences arise from assigning states greater responsibility for regulating chlorinated solvent waste.

The results presented here differ from those presented by Sigman for at least two reasons. First, Sigman used different data on state waste disposal tax rates than those used in the present study. This study used state waste disposal tax rates obtained through a LexisNexis search of state statutes from 1991 forward. Tax rates obtained in this way are virtually identical to those used by Levinson (1999a, 1999b) for the period 1991 to 1995. Levinson's tax data do not correspond to those used by Sigman for the years 1988 to 1990 that predated the availability of information from the LexisNexis search. Second, further analysis for the early years of the TRI program uncovered a possible problem with Sigman's results. She indicates that her finding of a strong negative association between waste disposal taxes and waste generation was based on a two-way fixed-effects analysis, whereas the analysis presented here finds essentially the same result when only plant effects are included. When time effects are added, the strong association between waste disposal taxes and waste generation is destroyed. In any case, models of interjurisdictional competition frequently demonstrate that such competition is inefficient. The empirical results presented here, however, suggest that because taxes on the disposal of this waste do not affect firm behavior, at least in the case of chlorinated solvent waste, this inefficiency does not arise.

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