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ABSTRACT

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 follows the "polluter pays" principle by placing retroactive liability on responsible firms. Yet this cost is borne by current shareholders who did not benefit from past low-cost waste management. This paper introduces a "beneficiary pays" principle that burdens consumers who benefitted from lower prices. An input-output model is developed to calculate the effects of alternative tax rules on output prices. We find: (1) that the increase in commodity prices contributed by current Superfund taxes is only a small fraction of the price increase that would have fully covered the cost of controlling hazardous waste; and (2) current Superfund taxes do not raise the prices of goods associated with the most pollution.

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1. Introduction

A widely accepted principle in judging the fairness of alternative environmental policies is that the polluter pays for the cost of pollution. A different principle of fairness, introduced in this paper, is that the cost of pollution is paid by whoever would benefit from the pollution. In many cases, consumers are the ultimate beneficiaries of production that does not cover environmental costs. If a producer is then forced to use cleaner production methods, or to pay an environmental tax per unit of pollution, these higher costs are likely to be passed on to consumers in the form of higher product prices. In such cases, the "polluter pays" principle yields the same result as the "beneficiary pays" principle.

In other important cases, however, the two principles yield different results. If the producer is forced to pay for past pollution, in a retroactive manner, the payment is essentially a fixed cost that does not affect marginal production. Even if the producer also must use cleaner methods for new output, the payment for past pollution is a sunk cost absorbed by current shareholders. It does not take anything from past consumers who enjoyed lower prices.

In this paper we apply these concepts to a good example of retroactive liability, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. This Act authorizes the US Environmental Protection Agency (EPA) to identify sites contaminated with hazardous wastes, to add them to the National Priorities List (NPL), to try to identify the Potentially Responsible Parties (PRPs) at each site, and then to try to make those parties clean up the site or pay for the clean up.

Any new generation of hazardous waste is regulated under the Resource Conservation and Recovery Act (RCRA), passed in 1976 and amended in 1984. Here, we discuss only past pollution under CERCLA.

For the part of cleanup costs that cannot be collected from PRPs, CERCLA established the Hazardous Substance Response Trust Fund, commonly known as "Superfund," financed by taxes on intermediate use of petroleum and chemical feedstocks. The Superfund Amendments and Reauthorization Act (SARA) of 1986 increased this budget from $1.6 billion to $8.5 billion over five years by adding a small tax on corporations' alternative minimum taxable income (AMTI). Even these funds are now deemed inadequate for complete cleanup, however, and policymakers are currently considering additional taxes on insurance or on other intermediate inputs. The fairness of these additional taxes can be analyzed using the framework of this paper.

We first discuss the conditions under which cost savings associated with past pollution would have been passed on to consumers. Sufficient conditions are constant returns to scale and perfect competition. Since producers then make zero excess profits, they could not benefit from pollution. We provide some evidence on the competitiveness in relevant industries, finding that many small producers were likely to pass most of the benefits forward to consumers.

Second, we discuss the impact of retroactive liability on particular firms. If new entrants or other firms can produce the same output without this extra cost, then the equilibrium price is unlikely to cover the cost of cleaning up past sites. In this case, the retroactive liability becomes a fixed cost borne by current shareholders. Since this law does not burden the beneficiary, it might be deemed unfair. If one accepts the beneficiary pays principle, the implication in this case is that PRPs would be released from liability at closed Superfund sites, and that costs would be covered by further taxes on consumers of products that were produced more cheaply in the past.

Third, therefore, we discuss additional taxes that might satisfy this principle. We build an input-output model to address these issues. The model helps us to estimate the ultimate impact on all prices when certain Superfund taxes are imposed on the intermediate use of some outputs. This model captures indirect effects on prices of commodities which themselves are produced using taxed commodities.

We use constant returns to scale and perfect competition in this input-output model to calculate the zero-profit prices that would have covered the costs of controlling hazardous wastes in the era before 1980. This model can be used to calculate the flat long-run marginal cost line for each of 98 goods. We thus obtain all 98 equilibrium prices with no need to specify demand functions. We also use the model to calculate prices under alternative tax regimes. Because input-output coefficients are fixed, and demand is not relevant, this model is not suited for analysis of the efficiency effects of externality-correcting taxation. We only discuss the equity effects of different burdens.

We find that: (1) current Superfund taxes increase prices by only a small fraction of the increase that would cover the full environmental cost; and (2) current Superfund taxes do not put the heaviest burdens on industries with the largest hazardous waste problems. That is, the pollution benefit that was acquired by consumers in the past is only partially redeemed by current taxes. We then use our input-output model to find a set of taxes that would best achieve the goal of putting more burden on the consumers of goods that had the largest waste problems.

2. CERCLA Liability

Retroactive liability means that PRPs must pay for actions that took place before the law was passed.[1] Also, the EPA may use "strict liability," which means that responsible parties must pay even if they were not negligent. Finally, "joint and several liability" means that any one PRP can be held liable for the entire cost of cleanup. These rules were thought to enable the EPA to collect higher fractions of cleanup costs, but they may have induced more

[1]The potentially responsible parties include (CERCLA, 42 U.S.C. § 9607 Liability): (1) the present owners and operators of the facility, (2) the previous owners and operators, (3) the generators of the hazardous substances, and (4) any transporters of such substances.

litigation, raised transactions costs, and slowed the pace of clean-up. Acton and Dixon (1992) report that 21 percent of PRP expenditures have gone to transactions cost, while Business Week (1992) reports that only 84 of the 1,245 sites on the NPL have completed cleanup.[2] Probst and Portney (1992) indicate that remaining sites may cost $45 billion, while other sites will be added to the list.

For the past thirteen years, since the enactment of CERCLA, several criticisms of these rules have been raised. Regarding strict liability, many PRPs complain that they are being punished for careful behavior which followed the law at the time. Regarding joint and several liability, in multiple-PRP sites, the identified parties complain that they are forced to contribute more than their share, to cover other responsible parties who are not yet identified or who have gone out of business. As a result, the identified PRPs try to find the unidentified parties and share the costs using private legal actions, litigation, and negotiation.[3] This paper does not address these two issues; instead, we discuss issues regarding retroactive liability.

In general, CERCLA liability is established on the commonly held principle that polluters pay for pollution. However, because this liability is retroactive, it is probably borne by current shareholders. In the era before CERCLA, did shareholders in these PRPs earn extra profits by not paying the full cost of proper disposal for hazardous wastes? More likely, these lower costs were passed through to customers in the form of lower prices. We use simple

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[2]This high transactions cost is a consequence of disagreement between the PRPs and the EPA, and among the PRPs on the estimation of appropriate shares of the cleanup liability. PRPs may hire their own investigators and then proceed to litigation or negotiation in order to seek a share of the cleanup liability that they think is fair. Acton and Dixon's (1992) study shows that the transaction costs are especially high for the insurers, and for the multiple-PRP sites rather than single-PRP sites.

[3] Probst and Portney (1992) note that "At least five separate tiers of litigation/settlement negotiations can occur: (1) between EPA and PRPs, (2) among settling parties, (3) between settling parties and non-settlers, (4) between PRPs and their insurers, and (5) between insurers and reinsurers" (pp. 13-14).

microeconomics in this section to introduce the "beneficiary pays" principle and to compare it with the "polluter pays" principle.

2.1 Who Received the Benefit?

Consider an industry with recognized PRPs, an industry such as chemicals, petroleum, or heavy metal and mining. In the era before the CERCLA, assume this industry had (1) constant return to scale and (2) perfect competition. With these assumptions, as shown in Figure 1, the long-run marginal cost curve was flat.

In Figure 1, the horizontal PMC represents private marginal cost excluding pollution cost. The SMC represents social marginal cost including both PMC and pollution cost. D is the demand curve, which also represents the marginal benefit (MB) of additional output. Under competitive conditions, if firms faced the flat private cost line, then the equilibrium price was p^{o} and excess profits were zero. If firms had been forced to pay social costs, however, the price would have been p'. Excess profits would still have been zero. Under these conditions, consumers received all of the benefits of low-cost disposal in extra consumer surplus ($p'acp^{o}$). Thus, although firms may actually have caused the pollution before CERCLA, they did not benefit from it.

These results depend on two key assumptions. First, what if constant returns to scale does not pertain to certain industries? Suppose firms' long-run marginal cost is not horizontal as in Figure 1, but a line of positive slope as in Figure 2. In this case, both the consumers and the shareholders of the firm would benefit from low-cost disposal of hazardous wastes. In Figure 2, if the cost of pollution is not internalized, the output is sold at price p^{o} instead of p'. The firms gain the area $p^{o}cbp''$, and the consumers gain surplus $p'acp^{o}$. If supply is more elastic than demand, as in Figure 2, then consumers benefited more than the shareholders.

Second, what if the assumption of perfect competition does not pertain? We return to the case of flat cost curves, but we replace the assumption of perfect competition with the opposite extreme of pure monopoly. In Figure 3, the monopolist sets its own marginal cost (PMC) equal to marginal revenue (MR) at point d, sells q_m^o at price p_m^o, and makes profit $p^o dcp_m^o$. If it had been forced to face social marginal cost, it would have sold q_m' at price p_m' for profit of $p' bap_m'$. The firm would have had lower profits, so it benefited from low-cost disposal. Consumers would have faced higher prices as well, however, so they also benefit by consumer surplus $p_m' acp_m^o$.

To provide some rough evidence on both of these assumptions, we check the structure of relevant industries in the era before CERCLA. A staff working paper of the Congressional Budget Office (CBO, 1985a) shows seventy industries at the 4-digit SIC level with hazardous waste problems.[4] To save space, Table 1 lists only the ten industries with the largest hazardous waste problems. The hazardous waste management cost for these ten industries ($3.89 billion) accounts for 67% of the total for the seventy industries ($5.77 billion). Column 1 shows the SIC code of each industry, and column 2 shows percentage of total annual pollution control cost. Column 3 shows the most commonly used measure of market power, the 4-firm market concentration ratio, defined as the percentage of total industry shipment values contributed by the largest four firms. Columns 4, 5 and 6 show concentration ratios for the largest 8, 20 and 50 firms. Column 7 is the industry description. The rows in Table 1 have been sorted by column 2.

Scherer (1979) reviews several measures of monopoly power and concludes that none provides a definite threshold to say whether a market is competitive. However, he suggests that an industry can be categorized as oligopolistic if its 4-firm concentration ratio is greater than 50%. In Table 1, only SIC 3041 (rubber, plastics hose, belting) has a 4-firm concentration ratio above 50% (although the ratio for 4200 is not available).

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[4] CBO's 1983 data on hazardous wastes are based on the Resource Conservation and Recovery Act (RCRA), passed in 1976. They might be somewhat different from the wastes covered by CERCLA.

Other industries are similar. Four-firm concentration ratios are below 50% for 41 of the 70 industries, and those 41 industries account for over 81% of total annual pollution control costs. We conclude that the relevant industries for our model are adequately competitive.

Table 1 also sheds light on our second assumption, that of constant returns to scale. Obviously, firms in some of these industries (like 3312, blast furnaces and steel mills) face a minimum efficient scale, but Table 1 shows that plenty of firms exceed that minimum. A significant fraction of output is produced by firms below the largest 8 and even below the largest 20. Since both large and small firms operate in the same market, we conclude that costs must be adequately similar all across the relevant range.

With these two assumptions, prices reflect private marginal costs. Thus consumers received most of the benefit of production that did not cover pollution costs.

2.2 Can CERCLA Liability be Transferred to Current Consumers?

CERCLA's retroactive liability asks PRP firms to pay for cleaning up past pollution in Superfund sites. Therefore, these PRPs might attempt to share this burden with their customers. If this liability is transferable, and consumers share part of the burden, then CERCLA liability may still place the ultimate burden on those who took the benefit. However, we think that this attempt is unlikely to succeed for the following reasons. First, as just demonstrated, each of the PRPs is a relatively small firm in its industry. These small firms cannot change their product price without considering competitors' responses. If a firm raises its price alone, competitors will usurp its market share. Second, even if all existing firms are PRPs, a successful increase in product prices would attract potential entrants who do not have to bear a retroactive liability. Thus CERCLA's retroactive liability functions as a fixed cost in a liable firm's production cost structure. This fixed cost does not influence a company's pricing at the margin. As a result, each PRP must bear its cost alone. In other words, the current liability system is not able to make the past beneficiaries pay for pollution.[5]

2.3 Polluter Pays or Beneficiary Pays?

Because PRPs are unlikely to transfer the liability to consumers, we must compare two different principles: the "polluter pays" or the "beneficiary pays". First, if we were to adopt the "polluter pays" principle, then we would put liability on the firms and thus impose loss on current shareholders who did not benefit in the first place. Moreover, if the shares have changed hands a few times since the low-cost disposal took place, then liability on the current shareholders does not even achieve the desired payments from those who did the pollution. Second, if we adopt the "beneficiary pays" principle, we would use only taxes and thus impose loss on current consumers. These consumers did not cause the pollution themselves, but they did benefit from it.

Quite possibly the current consumers are not the same individuals as the prior consumers who received the benefit of cheap disposal. In this case, unfortunately, no policy would be able to make the beneficiaries pay. We can only choose whether the Superfund tax is closer to the beneficiary principle than is the liability system.[6]

If policy must choose between the two principles, the "beneficiary pays" principle has certain advantages. It would avoid imposing windfall losses on shareholders who are not responsible for environmental damage. It would avoid costly litigation and delay, and it would acquire needed revenue from

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[5]Even if the liability can be transferred through higher prices to customers, then it is just functioning as a tax system. A liability system is not necessary in this case. A Superfund tax system would impose the same burdens, but it would avoid litigation and thus speed the pace of cleanup.

[6]A different sort of "benefit principle" would put the cost of a public project (such as a bridge) on those who benefit (such as those who cross the bridge). For toxic waste cleanup, however, the cost would be paid by neighbors of the site who "benefit" from the cleanup. This principle does not apply to Superfund, because cleanup only compensates neighbors for their prior loss from the existence of the site.

some of those who did benefit in the past. Finally, however, our argument must be limited to PRPs at Superfund sites that operated before CERCLA, or to the part of wastes that was generated before CERCLA. After 1980, PRPs might include their expected liability in product prices.

3. Existing Superfund Taxes

To the extent that liability rules do not pay for all cleanup, CERCLA uses Superfund, financed primarily by (1) taxes on petroleum, forty-two chemicals, and sixty-eight imported chemical substances, and (2) taxes on corporations' alternative minimum taxable income (AMTI) in excess of $2 million, called the corporate environmental tax (CET). The taxes on intermediate inputs of petroleum and chemicals apply to specific goods believed to be associated with hazardous wastes, whereas the CET reflects the concern that toxic waste is also generated by other industries. The CET was authorized by SARA in 1986 not only for reasons of equity but also for reasons of fiscal shortage.

Although only the firms are legally responsible to pay the tax, they can raise product prices and transfer some burden to consumers. As in Figure 2, the price might rise to p'. As we have discussed, firms are very unlikely to transfer their firm-specific CERCLA liability. They can only transfer tax burden to consumers when all firms face the same tax rates.

3.1 Petroleum Tax

Under CERCLA, a crude oil refiner is required to pay tax when crude oil is received at a US refinery. An importer also must pay tax when crude oil and petroleum products enter the US. Before January 1987, both the refiner and importer paid 0.79 cents per barrel of petroleum. From January 1987 to January 1989, the refiner paid 8.2 cents per barrel and the importer paid 11.7 cents per barrel. Because of international trade agreements, both refiner and importer now pay 9.7 cents per barrel. Table 2 presents tax revenues from 1987 to 1991, the period reauthorized by SARA. The first two rows show tax revenues from domestic and imported oil, while the subtotal is the sum over these two items. During the five year period, on average, petroleum tax revenue contributed 44.55% of total Superfund revenues.

3.2 Chemical Feedstock Tax

Also under CERCLA, tax is paid by firms on the use or sale of forty-two organic and inorganic chemicals. No tax rate changed, between CERCLA and SARA, except for xylene. The tax rates were set, originally in 1980, at $4.87 per ton for all organic chemicals and at $4.45 per ton for all inorganic chemicals. These rates were slightly revised in recent years with regard to some of the chemicals. The tax revenue is also presented in Table 2. On average, between 1987 and 1991, this tax contributed 23.64% of total Superfund revenues.

3.3 Imported Chemical Substances

SARA levies tax on the importers of fifty chemical substances. It now has been revised, as eighteen new chemical substances have been added to the list. Tax revenue during the SARA period is presented in Table 2, which shows that this tax contributed 0.48% of total Superfund revenue. Since this revenue is only a small contribution to the total, we do not include it in our input-output analysis. In any case: (1) our closed-economy model does not include imported items, and (2) the tax revenues from these fifty chemical substances are not disclosed, to avoid identifying the operation of individual companies.

3.4 Corporate Environmental Tax

SARA levies a tax of 0.12 percent on every corporation's alternative minimum taxable income (AMTI), in excess of $2 million, even if the firm does not pay AMT. During the SARA period, this corporate environmental tax (CET) gradually became more important in its contribution to Superfund. By 1991, the CET was the primary contributor to the fund (41.49%, as shown in Table 2).

4. Input-Output Analysis

To analyze the question of equity, or to estimate the burden on firms and consumers, we need to know the impact of each tax on the price of each output. In addition, if some industries use taxed commodities as intermediate inputs, then the burden is further shifted to the consumers of those outputs. We also want to measure the pattern of past benefits from low-cost disposal. Under constant costs and perfect competition, cost savings would have been passed through not only to consumers of goods such as chemicals and petroleum but also through to consumers of goods produced using chemicals and petroleum. We will look for a set of Superfund taxes that would be passed forward, through transactions among industries, to be borne ultimately by the same consumers who took the past benefit.

4.1 Input Coefficients

Input-output analysis was developed early in the 1950s by Wassily Leontief (1985). In its basic form, we assume that the national economy can be aggregated into n industries and a sector of final demand which includes household and government purchases. The dollar values of transactions among sectors can be presented in a transactions matrix:

$$(1) \qquad \mathbf{S} = \begin{bmatrix} x_{11}p_1 & x_{12}p_1 & \cdots & x_{1n}p_1 & d_1p_1 \\ x_{21}p_2 & x_{22}p_2 & \cdots & x_{2n}p_2 & d_2p_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{n1}p_n & x_{n2}p_n & \cdots & x_{nn}p_n & d_np_n \\ v_1 & v_2 & \cdots & v_n & \end{bmatrix}$$

where p_i represents the price per unit of product i, d_i is the final demand for output i, and v_i represents the value-added of the i^{th} industry. Each row represents the intermediate and final uses of an output, and each column represents the intermediate and factor inputs of an industry. For example, x_{21} is the physical quantity of the output from industry 2 that is used by industry 1. With no loss in generality, we use the unit price convention. We define the physical unit of each commodity as the amount that sells for one dollar. Since all prices are one, we can use dollar volume in (1) to derive the input coefficients. Let x_j be the sum of all demands in row j, a measure of total output. We then define a_{ij} as the "input coefficient," the input of the i^{th} good as a fraction of total output of industry j :

(2) $$a_{ij} = \frac{x_{ij}}{x_j}$$

where $$x_j = \sum_{i=1}^{n} x_{ji} + d_j$$

As in other static input-output analyses, we assume these input coefficients are constant. This assumption is useful and appropriate for calculating first-order effects on the cost of output from variations in the cost of various inputs, as we do here, but it does not account for second-order effects such as changes in the mix of inputs. These second-order effects would be necessary to estimate efficiency effects from tax distortions, or to estimate tax revenue after adjustments in behavior.

As long as profits are included in value-added, the sum of all inputs plus value-added is equal to the value of gross output. Also, the sum of all intermediate and final uses is equal to the value of gross output. Thus each column sum of matrix (1) is equal to the corresponding row sum:

(3) $$\begin{array}{c} x_{11}p_1 + x_{21}p_2 + \cdots + x_{n1}p_n + v_1 = x_1 p_1 \\ x_{12}p_1 + x_{22}p_2 + \cdots + x_{n2}p_n + v_2 = x_2 p_2 \\ \vdots \quad \vdots \quad \cdots \quad \vdots \quad \vdots \quad \vdots \\ x_{1n}p_1 + x_{2n}p_2 + \cdots + x_{nn}p_n + v_n = x_n p_n \end{array}$$

Then the input coefficients can be substituted in equations (3) to find:

$$
(4) \quad \begin{array}{l}
(1-a_{11})p_1 \quad - a_{21}p_2 - \cdots \quad - a_{n1}p_n = v_1/x_1 \\
- a_{12}p_1 + (1-a_{22})p_2 - \cdots \quad - a_{n2}p_n = v_2/x_2 \\
\vdots \qquad \vdots \qquad \cdots \qquad \vdots \qquad \vdots \\
- a_{1n}p_1 \quad - a_{2n}p_2 - \cdots + (1-a_{nn}p_n) = v_n/x_n
\end{array}
$$

These equations can then be represented by:

(5) $\quad (\mathbf{I}-\mathbf{A}')\mathbf{P} = \mathbf{V}$

where $\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$ $\quad \mathbf{P} = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix}$ $\quad \mathbf{V} = \begin{bmatrix} v_1/x_1 \\ v_2/x_2 \\ \vdots \\ v_n/x_n \end{bmatrix}$

and where $\mathbf{I}$ is the identity matrix. Assuming $(\mathbf{I}-\mathbf{A}')$ is nonsingular, the price vector can be derived as:

(6) $\quad \mathbf{P} = (\mathbf{I}-\mathbf{A}')^{-1}\mathbf{V}$

In a closed economy, where prices are not already set by international trade, this equation can be used to calculate the impact of alternative policies on the price vector $\mathbf{P}$.

4.2 Target Prices

In order to calculate the benefit to consumers of past low-cost disposal, we need to know the prices they would have had to pay if firms had used current safer disposal methods. Call this set of prices the "target" price vector. In this paper we use the target price vector as the standard of comparison for each alternative policy.

Assume that the firms had complied with current environmental regulations, in the past, by an additional expenditure either for capital or labor. As suggested by CBO (1985b, pp. 28-30), suppose e_i is this additional compliance expenditure as a fraction of value-added for the i^{th} industry. Full compliance value-added is then $v_i(1+e_i)$. The firms are assumed to take care of their industrial wastes themselves, in this case, and the government does not have to collect any money to clean up disposal sites. The target price vector is derived as:

(7) $\hat{\mathbf{P}} = (\mathbf{I} - \mathbf{A}')^{-1}\mathbf{EV}$

where $$\mathbf{E} = \begin{bmatrix} 1+e_1 & 0 & 0 & 0 \\ 0 & 1+e_2 & 0 & 0 \\ 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & 1+e_n \end{bmatrix}$$

Since the $\hat{\mathbf{P}}$ are the prices that reflect the "true" cost of each output, we can use this price vector as a basis for comparing the various possible tax instruments.

4.3 Intermediate Input Tax and Corporate Environmental Tax

The intermediate input tax and the CET are the two major financial instruments used to collect money for Superfund. The intermediate input tax is imposed on each industry's intermediate input of petroleum and chemical feedstocks. If each intermediate input has its own tax rate (regardless of where it is used), then (3) can be expressed as:

(8)
$$\begin{matrix} x_{11}p_1(1+t_1) + x_{21}p_2(1+t_2) + \cdots + x_{n1}p_n(1+t_n) + v_1 = x_1p_1 \\ x_{12}p_1(1+t_1) + x_{22}p_2(1+t_2) + \cdots + x_{n2}p_n(1+t_n) + v_2 = x_2p_2 \\ \vdots \qquad \vdots \qquad \cdots \qquad \vdots \qquad \vdots \qquad \vdots \\ x_{1n}p_1(1+t_1) + x_{2n}p_2(1+t_2) + \cdots + x_{nn}p_n(1+t_n) + v_n = x_np_n \end{matrix}$$

Using steps similar to those used in deriving equations (3) to (6), we then have:

(9) $\tilde{\mathbf{P}} = (\mathbf{I} - \mathbf{T_I}\mathbf{A}')^{-1}\mathbf{V}$

where $$\mathbf{T_I} = \begin{bmatrix} 1+t_1 & 0 & 0 & 0 \\ 0 & 1+t_2 & 0 & 0 \\ 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & 1+t_n \end{bmatrix}$$

We can consider CET in our model, also. Assuming that all industries face the same rate of CET, say t, and that the taxable AMTI of each industry is a fraction, α_i, of the value-added of the i^{th} industry, then:

(10) $\tilde{\mathbf{P}} = (\mathbf{I} - \mathbf{T_I}\mathbf{A}')^{-1}\mathbf{T_C}\mathbf{V}$

where $$\mathbf{T_C} = \begin{bmatrix} 1+t\times\alpha_1 & 0 & 0 & 0 \\ 0 & 1+t\times\alpha_2 & 0 & 0 \\ 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & 1+t\times\alpha_n \end{bmatrix}$$

We now have $\tilde{\mathbf{P}}$ as the set of prices calculated from a particular set of tax rules (and input-output coefficients). We also have $\hat{\mathbf{P}}$ as a "target," that is, the prices that would have been paid by consumers if firms had been forced to internalize all environmental costs of disposal. The next question is: can we get $\tilde{\mathbf{P}}$ to match $\hat{\mathbf{P}}$? If $\tilde{\mathbf{P}}$ is close to $\hat{\mathbf{P}}$, through the market mechanism, then beneficiaries would pay back an amount equal to the benefit received in the past.

Conceptually, equivalence can be achieved in two ways. First, let $\mathbf{T_I}$ be an identity matrix (with no intermediate taxes at all). Then $\tilde{\mathbf{P}} = \hat{\mathbf{P}}$ can be obtained from (7) and (10) if:

(11) $$(\mathbf{I} - \mathbf{A}')^{-1}\mathbf{T_C}\mathbf{V} = (\mathbf{I} - \mathbf{A}')^{-1}\mathbf{E}\mathbf{V}$$

This equation holds if $\mathbf{T_C} = \mathbf{E}$. That is, if Congress could somehow set the CET rate for each industry equal to the environmental cost for that same industry, the target price $\hat{\mathbf{P}}$ is achieved. For two reasons, however, Congress is unlikely to consider this solution. First, an income tax traditionally applies at a single rate to some general definition of taxable income. It may be deemed unfair if the rate varied by industry. Second, it may be difficult to administer or enforce, since a single firm may operate in more than one industry. Costs may be shifted artificially from a low-rate industry to a high-rate industry. A more feasible system would impose different excise tax rates on different commodities. Therefore, a second approach is to find a set of $\mathbf{T_I}$ such that $\tilde{\mathbf{P}} = \hat{\mathbf{P}}$, which means that:

(12) $$(\mathbf{I} - \mathbf{T_I}\mathbf{A}')^{-1}\mathbf{T_C}\mathbf{V} = (\mathbf{I} - \mathbf{A}')^{-1}\mathbf{E}\mathbf{V}$$

Using matrix algebra, this expression can be solved for the necessary input taxes:

(13) $$\mathbf{T_I} = \mathbf{A}'^{-1} - \mathbf{T_C}\mathbf{E}^{-1}\mathbf{A}'^{-1} + \mathbf{T_C}\mathbf{E}^{-1}$$

In (13), although $\mathbf{T_C E^{-1}}$ is a diagonal matrix, $\mathbf{A'^{-1} - T_C E^{-1} A'^{-1}}$ is not. Therefore, $\mathbf{T_I}$ is not a diagonal matrix. That is, the $\mathbf{T_I}$ of (13) would impose different tax rates on different users of the same intermediate inputs. We believe that this solution also is difficult to administer and unacceptable to Congress. As a consequence, no feasible tax policy achieves $\tilde{\mathbf{P}} = \hat{\mathbf{P}}$ exactly. We turn latter to the problem of finding a "real-world" set of taxes that might best approximate the target, getting $\tilde{\mathbf{P}}$ close to $\hat{\mathbf{P}}$. We will use numerical methods to find the set of two or three inputs that could be taxed, each with its own rate for all users, such that $\tilde{\mathbf{P}}$ is as close as possible to $\hat{\mathbf{P}}$.

Finally, with regard to these taxes, we have not specified the number of years necessary to collect enough revenue to pay for Superfund cleanups. A potential problem is that these cleanups may cost a lot more than was saved in years past by inadequate management practices. If cleanup is financed by multi-year taxes that make $\tilde{\mathbf{P}}$ close to $\hat{\mathbf{P}}$, consumers may ultimately pay more than they benefited. In addition, even without taxes, consumers would currently be paying for the cost of waste management practices regulated under RCRA.

4.4 Data

The Bureau of Economic Analysis (BEA) publishes the benchmark input-output accounts every five years, and 1982 is the most recent year available (U.S. Department of Commerce, 1991). These accounts classify all firms into 541 industrial categories, equivalent to the SIC code at the 4-digit level. We retain the seventy detailed industries (CBO, 1985a) that have toxic waste by-products, and we aggregate the other industries into twenty-eight sectors. Table 3 presents our aggregation. Column 1 gives our identification number for each industry, and column 2 provides the related SIC code(s). Column 3 gives the description of each industry.

One problem in using this benchmark data is that the transactions are subdivided into a make-matrix ($\mathbf{M_{I \times C}}$) which shows how much each industry makes of each commodity, and a use-matrix ($\mathbf{U_{C \times I}}$) which shows how much of each commodity is used by each industry. To derive the industry-by-industry transactions matrix ($\mathbf{S}_{I \times I}$), we need to divide each entry of $\mathbf{M}_{I \times C}$ by its column sum and then multiply:

(14) $\mathbf{S}_{I \times I} = \mathbf{M}_{I \times C} \times \mathbf{U}_{C \times I}$

When we include another row and column for value-added and final demand, we have the S matrix of equation (1). We then derive A from the units convention and equation (2).

Since insufficient pollution control was undertaken in the era before the Superfund law, we have no exact data for **E** in equation (7). We use some currently estimated pollution control expenditures instead. The most appropriate available information is in CBO (1985a). For each of the seventy industries at the SIC 4-digit level, this study provides the estimated annual quantity of toxic wastes and the average control cost per ton. It is summarized in Table 4. After the ID number in column 1, we take the cost per metric ton in column 2 and multiply by the number of metric tons in column 3 to get our estimated annual cost for each industry in column 4. These amounts are divided by value-added to get the e_i for our **E** matrix.

Data for $\mathbf{T}_I$ and $\mathbf{T}_C$ are available in the memorandum by Dougherty and Gilson (1992). With statistics on petroleum tax receipts in their exhibit 4, divided by value-added in petroleum, we have the estimate for t_{32} of $\mathbf{T}_I$. With the exception of cupric compounds and chloride compounds of inorganic chemicals in their exhibit 5, we aggregate chemical feedstock tax receipts into our 98-industry system according to their SIC classification. The t_i for each chemical in $\mathbf{T}_I$ is just the ratio of tax receipts for that chemical divided by its own value-added.

Their exhibit 8 provides the necessary information for $\mathbf{T}_C$. To arrive at our 98-industry breakdown, we need to aggregate some of their items to our twenty-eight entries that are equivalent to the SIC 2-digit level. We also need to disaggregate their other items to our seventy entries that are equivalent to the

SIC 4-digit level. The disaggregation assumes that tax receipts are proportional to each industry's total output. For example, the tax receipt of SIC 28 (chemicals and allied products) in exhibit 8 was about $38.8 million in 1989. According to our 98-industry classification system, SIC 28 is broken-down into the eighteen industries with our numbers 13 to 30. Then this $38.8 million is assigned in proportion to output of these eighteen industries.

5. Applications of the Input-Output Model

With the input-output model, we will estimate (1) the impact on prices of current Superfund taxes, (2) how the current petroleum and chemical feedstock taxes and CET could be adjusted to closer approximate the target prices, (3) the impact on prices of imposing a tax on casualty insurers (SIC 6331), currently being debated, and (4) what other industries could be taxed to help approximate the target price vector.

In section 4.3 we argued that an exact solution for $\tilde{\mathbf{P}}$ to match $\hat{\mathbf{P}}$ is not politically viable. We now turn to find a more realistic policy that would make $\tilde{\mathbf{P}}$ as close as possible to $\hat{\mathbf{P}}$. For this purpose, we need to minimize a measure of distance. Our first measure of distance is the sum of the squares of the differences between each estimated price and its target price:

(15) $$\Delta = \sum_{i=1}^{98} (\tilde{p}_i - \hat{p}_i)^2$$

An alternative is the sum of the absolute values of these differences:

(16) $$\Delta = \sum_{i=1}^{98} \left| \tilde{p}_i - \hat{p}_i \right|$$

If Congress chooses another industry to tax, then we can compare the new Δ and the old Δ to see whether the Superfund tax system becomes closer to a beneficiary tax.

However, the distance functions of (15) and (16) do not consider the differences in size of the ninety-eight industries. The search might skip the opportunity to place a tax on an industry with a large total amount of pollution, in order to place a tax instead on an industry with a high ratio of pollution cost to price. To account for the size of industries, we could weight the distances, as in:

(17) $$\Delta = \sum_{i=1}^{98} (\tilde{p}_i - \hat{p}_i)^2 \times w_i$$

and

(18) $$\Delta = \sum_{i=1}^{98} \left| \tilde{p}_i - \hat{p}_i \right| \times w_i$$

where w_i is each industry's output divided by the total of all industries' output. Note that the multiplication of the price difference ($\tilde{p}_i - \hat{p}_i$) by output in (18) just yields the total pollution cost of that industry. With this weighting, the use of distance functions (17) and (18) can help pick the industries that have large pollution management costs.

5.1 The Impact on Prices of Current Superfund Taxes

By substituting **A**, **V** and **E** into equation (11), we arrive at the target price vector ($\hat{\mathbf{P}}$). By substituting **A**, **V**, **E**, $\mathbf{T}_\mathbf{I}$ and $\mathbf{T}_\mathbf{c}$ into equation (14), we also derive the price vector ($\tilde{\mathbf{P}}$). With this difference in prices, for current Superfund taxes, the four distance functions are shown in the first row of the table below:

	$\Sigma(\tilde{p}_i - \hat{p}_i)^2$	$\Sigma\lvert \tilde{p}_i - \hat{p}_i \rvert$	$\Sigma(\tilde{p}_i - \hat{p}_i)^2 w_i$	$\Sigma\lvert \tilde{p}_i - \hat{p}_i \rvert w_i$
Δ for current Superfund taxes	0.0952	1.286	$5.776*10^{-5}$	$2.383*10^{-3}$
max Δ, for no taxes at all	0.0973	1.371	$6.187*10^{-5}$	$2.784*10^{-3}$

The second row of the table shows an upper bound for each distance function, from a calculation with no taxes at all. Since the current Δ are only slightly less than these upper bounds, we conclude that the current tax system is not a good approximation to a beneficiary tax. We will search for taxes that minimize this distance.

Figure 4 shows the non-weighted price vector under current Superfund taxes, in black bars, and the target price vector in white bars. It shows that the price increases caused by current Superfund tax rates are still considerably less than the price increases that would result if hazardous waste management cost were covered in production costs. An exception is industry 32, petroleum refining, in which the current price is higher than the target price.

We also estimate separately the price effects of each tax. Price increases attributable to the current CET are too small to see in Figure 4. Chemical feedstock taxes mainly increase prices of industry 14 (alkalies and chlorine), 25 (cyclic crudes and intermediates) and 26 (industrial organic chemicals, not elsewhere classified). The petroleum tax mainly increases the price of industry 32 (petroleum refining).

In Figure 4, we also find that the current tax system does not hit the industries that generated heavy pollution. In terms of pollution management cost as a fraction of goods' value, the top three industries are 62 (plating and polishing), 37 (rubber, plastics hose, belting), and 47 (gray iron foundries). None of the four industries that are hit by current Superfund taxes (14, 25, 26 and 32) are within the list of the top-three pollution generators. This finding seems to suggest that the current use of taxes on petroleum and chemical feedstocks is unfounded. The original motivation was that petroleum and chemicals are the major sources of toxic wastes, but the problem is that most of the toxic wastes are generated in complex compound forms. Generally, these toxic wastes are dangerous not because they use petroleum or chemicals as inputs, but because users undertake some chemical reactions to produce their products and thereby generate some dangerous chemical by-products. In other words, pollution is not caused by petroleum or chemicals themselves but by the ways that users employ them. The point here is not that current taxes on petroleum or chemicals be repealed, but only that some other goods might also be taxed in order to collect from the consumers who have paid artificially low prices in the past.

5.2 An Increased Rate of Current Superfund Taxes

In our first simulation, we adjust the current CET, petroleum and chemical feedstock taxes to see how much the Δ can be reduced. By all four objective functions, we find that any increase of tax rates on petroleum and chemical feedstocks would only raise the Δ. Therefore we try adjusting the CET alone, with and without petroleum and chemical feedstock taxes. The results are listed in the following table.

	$\Sigma(\tilde{p}_i - \hat{p}_i)^2$		$\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert$		$\Sigma(\tilde{p}_i - \hat{p}_i)^2 w_i$		$\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert w_i$	
	CET Rate	Δ	CET Rate	Δ	CET Rate	Δ	CET Rate	Δ
Current Taxes	.12%	0.0952	.12%	1.286	.12%	$5.776*10^{-5}$	.12%	$2.383*10^{-3}$
Best CET no other†	4.7%	0.0842	2.5%	1.070	1.9%	$5.075*10^{-5}$	1.4%	$1.961*10^{-3}$
with other‡	4.4%	0.0843	2.3%	1.066	1.7%	$5.048*10^{-5}$	1.2%	$1.956*10^{-3}$

† Best CET of this row are derived without petroleum and chemical feedstock taxes

‡ Best CET of this row are derived with current petroleum and chemical feedstock taxes

These results suggest that the Δ under current taxes can be reduced by an increase in the rate of CET. When petroleum and chemical feedstock taxes are kept at current levels, the first distance function would be minimized if the CET is increased to 4.4%. Figure 5 shows the estimated prices in this case. A visual scan over the black bars in Figure 5 indicates that many industries are over-taxed in this case. As an alternative, Figure 6 shows the estimated prices with a 1.2% CET rate, derived using the weighted sum of absolute values ($\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert w_i$). With the tax rate of 1.2%, fewer industries are over-taxed and this Δ falls by 18%. Thus the beneficiary pays principle could be better approximated by a ten-fold increase in the current 0.12% rate of the corporate environment tax.[7]

5.3 Tax on Property and Casualty Insurers

Recent policy proposals include a tax on property and casualty insurers to help finance Superfund. Therefore, in our second simulation, we fix the current Superfund tax rates at current levels and vary a new tax rate on insurers. In our 98-industry classification system, property and casualty insurers are included in industry 96 (insurance carriers). Hence, we vary t_{96} in $\mathbf{T_I}$ of equation (10) in search of the minimum Δ. Regardless of distance function, we find that no tax on industry 96 can reduce the Δ to less than under current Superfund taxes. That is, levying a tax on insurance carriers is no help in improving the degree to which the Superfund financial system satisfies the principle of "beneficiaries pay".

5.4 Best One Additional Instrument

Various proposals discussed in Probst and Portney (1992) would release some PRPs from liability at some Superfund sites, such as those operated before CERCLA. If any of these alternatives is adopted, then Superfund would need more sources to foot the bill. Thus, in the following, we are interested in finding the most suitable industries to pay the cost of cleanup. For our next set of simulations, we assume that Congress would like to add a tax on one intermediate input while keeping other current taxes on petroleum, chemical feedstocks, and CET.

To find the best additional instrument, we vary each t_i of $\mathbf{T_I}$, one at a time, to search for the tax rate that minimizes Δ. Table 5 shows results with respect to the four distance functions, where column 1 is the identification (ID) numbers of the industry, column 2 is the tax rate, and column 3 is the minimum Δ. Entries in Table 5 are sorted by column 3; hence, the instrument with the

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[7] This tenfold increase might raise CET revenues from $591 million per year (Table 2) to $5.9 billion per year (with no behavioral changes) and thus pay for the total $45 billion cleanup within eight years.

largest impact on Δ is listed first. For the first three distance functions, the tax that most reduces Δ would apply to intermediate use of output number 62, plating and polishing. An anomalous finding arises with the fourth distance function ($\Sigma|\tilde{p}_i - \hat{p}_i| w_i$), the sum of weighted absolute values of price differences. This distance function identifies industry 49 (primary zinc) as the best instrument, and levies a 472.0% tax on this input. Because this tax rate is unrealistic, we turn to the second entry in that column which shows that an 8.2% tax rate on industry 43 (blast furnaces and steel mills) would provide the second-most reduction in that Δ. In general, however, three out of the four distance functions suggest that industry 62 would be the best single instrument.

5.5 Best Two and Three Instruments

In the next two simulations, we presume that Congress is interested in levying Superfund tax on two or three more industries. To find the best two (or three) instruments, conceptually, we need to search through every combination of the ninety-eighty industries to find the best pair (or trio). An unstructured search would take much computer time, so we use the results in Table 5 for our initial guesses. We try all possible combinations of the top-five industries listed in that table, and we also try combinations picked by the other distance functions. The results of the search for the best two instruments are listed below.[8]

	(1) $\Sigma(\tilde{p}_i - \hat{p}_i)^2$		(2) $\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert$		(3) $\Sigma(\tilde{p}_i - \hat{p}_i)^2 w_i$		(4) $\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert w_i$	
max Δ =	0.0973		1.371		$6.187*10^{-5}$		$2.784*10^{-3}$	
current Δ =	0.0952		1.286		$5.776*10^{-5}$		$2.383*10^{-3}$	
derived Δ =	0.0246		0.829		$2.224*10^{-5}$		$1.439*10^{-3}$	
	ID	tax	ID	tax	ID	tax	ID	tax
	62	37.8%	62	36.6%	62	39.0%	43	5.0%
	37	24.7%	93	16.8%	47	18.6%	17	24.8%

[8] Even though we did not try all combinations, we tried enough to be extremely confident that these results minimize Δ over all possible combinations.

Column (1) shows that industry 62 (plating and polishing) and 37 (rubber, plastics hose, belting) are the best two additional instruments when distance is measured by the function $\Sigma(\tilde{p}_i - \hat{p}_i)^2$. The derived tax rate for industry 62 is 37.8%, and for 37 is 24.7% (see tax column). For the other distance functions, the newly introduced industries are: 93 (wholesale trade), 47 (gray iron foundries), 43 (blast furnaces and steel mills), and 17 (industrial inorganic chemicals, not elsewhere classified).

Since each distance function has its own best two instruments, a policymaker might have to decide which measure is most appropriate. The first or second measures might be preferred if the goal of policy is to place a tax on each item that best reflects the direct and indirect pollution costs of producing that item, regardless of the total amount of pollution. On the other hand, the third or fourth measures might be preferred if the goal is to collect from consumers of goods that are associated with the largest total amounts of pollution. A dilemma still exists, however, in the choice between the sum of squares or the sum of absolute values. This question is partially answered by the next simulation.

The results of the search for the best three instruments are listed below.

	$\Sigma(\tilde{p}_i - \hat{p}_i)^2$		$\Sigma\|\tilde{p}_i - \hat{p}_i\|$		$\Sigma(\tilde{p}_i - \hat{p}_i)^2 w_i$		$\Sigma\|\tilde{p}_i - \hat{p}_i\| w_i$	
max Δ =	0.0973		1.371		$6.187*10^{-5}$		$2.784*10^{-3}$	
current Δ =	0.0952		1.286		$5.776*10^{-5}$		$2.383*10^{-3}$	
derived Δ =	0.0163		0.758		$1.669*10^{-5}$		$1.273*10^{-3}$	
	ID	tax	ID	tax	ID	tax	ID	tax
	62	37.8%	62	37.6%	62	38.8%	62	64.4%
	37	24.7%	37	25.4%	47	18.8%	47	40.4%
	47	17.5%	47	17.2%	17	10.2%	17	25.4%

In this case, the dilemma is resolved. Whether the distance function uses the sum of squares or the sum of absolute values, the same industries are taxed. The two non-weighted distance functions both identify industries 62, 37 and 47 as the best three instruments, whereas both weighted functions identify industries 62, 47 and 17. These results also indicate that the sum of squares criterion may be more stable than the sum of absolute values, because the best combination of two industries is still part of the best combination of three industries. This result may be important in the choice of two industries to tax first, especially if a third industry might be added later. Use of the sum of squares criterion would allow the later addition of a third good to tax, whereas the use of the sum of absolute values criterion would require removing a tax on one of the first two goods, and then adding two new goods to tax. In the unweighted case, for example, the absolute values criterion would first tax goods 62 and 93. Then if policymakers wish to raise more revenue and tax three industries, they must drop 93 and tax 62, 37, and 47. This problem can be avoided by using just the sum of squares criterion (for either the unweighted case or the weighted case).

Figure 7 represents the price vectors when industries 62, 37, and 47 are imposed with tax rates of 37.8%, 24.7%, and 17.5%, respectively. It indicates that the tax system would track the full-cost prices of those three goods fairly closely, but would not provide a general agreement between cum-tax prices and target prices.

6. Conclusions

In this paper, we make two main points. First, if the seventy industries with hazardous waste problems in the era before CERCLA had constant return to scale and perfect competition, then polluting firms received no abnormal returns and thus were not the beneficiaries of cheaper hazardous waste management. Given these assumptions, the consumers received the benefit. We question the commonly used principle of "polluter pays," in this case, because any retroactive liability on firms would burden current shareholders. Instead, a different principle would hold that the beneficiary pay. With this principle, the cleanup cost is collected from consumers, not from firms. An implication is that potentially responsible parties (PRPs) who are liable for the sites operated before

CERCLA be released from liability. This release would probably also avert litigation, reduce transaction cost, and speed the pace of cleanup.

Second, although the release of some PRPs from CERCLA liability may help to reduce transaction cost, it also cuts an important source of revenue for cleanup of Superfund sites. More tax revenue may be needed to fulfill cleanup goals. Because the burden can be placed on consumers who benefited from past pollution, Superfund taxes may be used to collect the needed revenue. Hence, several tax alternatives are considered: (1) increase current Superfund tax rates, (2) increase the corporate environmental tax only, (3) place a tax on property and casualty insurers, and (4) add taxes on the intermediate input of other goods.

We measure the "distance" between full-cost prices and cum-tax prices. With the application of our input-output model, we find: (1) in the current Superfund tax system, if petroleum and chemical feedstock taxes are kept at the current level, and the tax rate of CET is increased to 1.2%, the distance function can be reduced by 18%; (2) levying tax on property and casualty insurers does not help reduce the distance; (3) if the goal of policy is to collect an amount close to the pollution control cost in the production of each item, using unweighted differences, then industry 62 (plating and polishing) is the one additional input to tax, 62 and 37 (rubber plastics hose, belting) are two inputs to tax, and the addition of 47 (gray iron foundries) provides three inputs to tax for the finance of Superfund; (4) if the goal is to collect tax that closely reflects the total amounts of pollution, using weighted differences, then 62 is one additional input to tax, 62 and 47 are two inputs to tax, and the addition of 17 (industrial inorganic chemicals) provides three inputs to tax for the finance of Superfund.

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Table 1: Market concentration ratios for the ten industries with the largest hazardous waste problems†

SIC code	percentage of total annual pollution control cost	Concentration Ratios: 4 largest	8 largest	20 largest	50 largest	Description
3471	11.53%	7.8	11.3	17.4	23.6	plating and polishing
3312	8.88%	48.9	66.8	83.9	95.6	blast furnaces and steel mills
3079	8.79%	7.8	12.2	20.0	32.0	miscellaneous plastics products
2819	8.49%	33.5	50.5	75.0	91.5	industrial inorganic chemicals, NEC
3321	7.14%	27.3	36.7	49.7	66.8	gray iron foundries
2869	6.61%	47.6	61.8	78.8	92.6	industrial organic chemicals, NEC
3900‡	4.56%	35.0	46.6	62.2	75.6	miscellaneous manufacturing and manufacturing not allocable
4200	3.97%	NA	NA	NA	NA	motor freight transport
3041	3.93%	53.5	71.5	89.0	98.0	rubber plastics hose, belting
2821	3.55%	24.0	39.0	62.5	88.5	plastics material and resins
sum	67.46%					

†Sorting is by the column 2, percentage of total annual hazardous waste control costs. Concentration ratios are averaged over the 1935-77 period.

‡Industry 3900 includes twenty sub-industries of the SIC 4-digit level. The ratios in this row are the average of these twenty industries for 1977 only.

NA: Not available for industry 4200.

Source: U.S. Department of Commerce (1980). "Concentration Ratios in Manufacturing." Census of Manufactures.

Table 2: Revenues of Superfund Taxes from 1987 to 1991

	Tax receipts ($ million)					
	1987	1988	1989	1990	1991	total
Petroleum tax						
Domestic	208.1	229.3	247.4	295	305.4	1285.2
Imported	210.7	273.5	347.2	276.7	242	1350.1
subtotal	418.8	502.8	594.6	571.7	547.4	2635.3
Percentage†	47.16%	45.29%	51.10%	43.03%	38.43%	44.55%
Chemical feedstock tax						
Organic	224.8	241.3	219.4	236.8	227.0	1149.4
Inorganic	48.5	53.0	50.0	49.4	47.9	248.8
subtotal	273.3	294.3	269.4	286.3	274.9	1398.2
Percentage	30.77%	26.51%	23.15%	21.55%	19.30%	23.64%
Imported chemical substances tax			7.8	9.7	11.1	28.6
Percentage			0.67%	0.73%	0.78%	0.48%
Corporate environmental tax	196.0	313.0	291.9	461.0	591.1	1853.0
Percentage	22.07%	28.20%	25.08%	34.70%	41.49%	31.33%

†The percentage of total annual Superfund revenue.

Source: Dougherty and Gilson (1992).

Table 3: Our aggregation to 98 industries

ID	SIC	description
1	01/02/ 07/08/09	AGRICULTURE, FORESTRY, AND FISHERIES
2	10/11/12/13/14	MINING
3	15/16/17	CONSTRUCTION
4	20	Food and kindred products
5	21	Tobacco manufactures
6	22	Textile mill products
7	23	Apparel and other textile products
8	24	Lumber and wood products (exc. next entry)
9	2491	wood preserving
10	25	Furniture and fixtures
11	26	Paper and allied products
12	27	Printing and publishing
13	28	Chemicals and allied products (exc. next 17 entries)
14	2812	alkalis and chlorine
15	2813	industrial gases
16	2816	inorganic pigments
17	2819	industrial inorganic chemicals, NEC
18	2821	plastics material and resins
19	2822	synthetic rubber
20	2823	cellulosic manmade fibers
21	2824	noncellulosic organic fibers
22	2833	medicinals
23	2851	paints and allied products
24	2861	gum and wood chemicals
25	2865	cyclic crudes and intermediates
26	2869	industrial organic chemicals, NEC
27	2879	agricultural chemicals, NEC
28	2892	explosives
29	2893	printing ink
30	2899	chemical preparations, NEC
31	29	Petroleum and coal products (exc. next 2 entries)
32	2911	petroleum refining
33	2922	lubricating
34	30	Rubber and miscellaneous plastics products (exc. next 5 entries)
35	3011	tires and inner tubes
36	3021	rubber and plastic footwear
37	3041	rubber plastics hose, belting
38	3069	fabricated rubber products, NEC
39	3079	miscellaneous plastics products
40	31	Leather and leather products
41	32	Stone, clay and glass products
42	33	Primary metal industries (exc. next 14 entries)
43	3312	blast furnaces and steel mills
44	3313	electro metallurgical products
45	3315	steel wire and related products
46	3317	steel pipe and tubes
47	3321	gray iron foundries
48	3325	steel foundries, NEC
49	3333	primary zinc
50	3339	primary nonferrous metals, NEC
51	3341	secondary nonferrous metals

Table 3: Our aggregation to 98 industries (continued)

ID	SIC	description
52	3351	copper rolling and drawing
53	3353	aluminum sheet, plates, and foil
54	3356	nonferrous rolling, drawing, NEC
55	3398	metal heat treating
56	3399	primary metal products, NEC
57	34	Fabricated metal products (exc. next 6 entries)
58	3411	metal cans
59	3452	bolts, nuts, rivets, washers
60	3465	automotive stampings
61	3469	metal stampings, NEC
62	3471	plating and polishing
63	3479	metal coating and allied services
64	35	Machinery, except electrical (exc. next 9 entries)
65	3531	construction machinery
66	3541	machine tools metal cutting
67	3544	special dies, tools, jigs
68	3551	food products machinery
69	3553	woodworking machinery
70	3555	printing trades machinery
71	3559	special industry machinery, NEC
72	3573	electronic computering equipment
73	3585	refrigeration and heating equipment
74	36	Electrical and electronic equipment (exc. next 8 entries)
75	3621	motors and generators
76	3622	industrial controls
77	3624	carbon and graphite products
78	3671	electron tubes
79	3674	semiconductors and related services
80	3679	electronic components, NEC
81	3691	storage batteries
82	3692	primary batteries, dry and wet
83	37	Motor vehicles and equipment (exc. next 5 entries)
84	3711	motor vehicles and car bodies
85	3714	motor vehicle parts and accessories
86	3721	aircraft
87	3724	aircraft engines and engine parts
88	3728	aircraft equipment, NEC
89	38	Instruments and related products
90	39	Miscellaneous manufacturing and manufacturing not allocable
91	40/.../49	TRANSPORTATION AND PUBLIC UTILITIES (exc. next entry)
92	42	Motor freight transport
93	50/51	WHOLESALE (drum reconditioners is in this section)
94	52/.../59	RETAIL TRADE
95	60/61/62/67	four of the FINANCE, INSURANCE, AND REAL ESTATE
96	63	insurance carriers (=SIC 6331)
97	64/65/66	three of the FINANCE, INSURANCE, AND REAL ESTATE
98	70/.../89	SERVICES & GOVERNMENT ENTERPRISES & SPECIAL INDUSTRIES

Note: Starting with the BEA 541 classification system which is similar to the SIC 4-digit classification system, we leave the 70 industries with toxic waste problems, and aggregated others into 28 sectors.

Table 4: CBO estimated average unit control cost, annual physical quantity generated, and annual total control cost of toxic wastes for seventy industries†

ID (1)	Average unit cost ($/MT‡) (2)	annual physical quantity (MT*1,000) (3)	Annual total cost (million $) (4)	ID (1)	Average unit cost ($/MT) (2)	annual physical quantity (MT*1,000) (3)	Annual total cost (million $) (4)
62	33.4	19912.0	665.06	52	69.1	267.6	18.49
43	20.7	24744.8	512.22	56	62.7	281.3	17.64
39	58.1	8722.9	506.80	14	3.6	4871.5	17.54
17	13.4	36545.3	489.71	50	68.5	231.5	15.86
47	34.2	12044.7	411.93	82	58.2	240.0	13.97
26	8.2	46492.0	381.23	61	111.5	113.4	12.64
90	47.5	5538.7	263.09	29	86.9	132.1	11.48
92	106.1	2160.0	229.18	81	88.9	115.0	10.22
37	44.8	5054.7	226.45	73	87.0	116.5	10.13
18	40.6	5045.4	204.84	49	19.7	509.9	10.04
85	59.9	2528.8	151.48	88	75.6	126.2	9.54
27	6.6	19683.2	129.91	87	129.9	58.9	7.65
80	82.8	1490.4	123.40	67	103.0	73.5	7.58
65	37.4	3268.4	122.24	19	31.8	204.6	6.51
32	3.7	30992.3	114.67	93	132.0	45.0	5.93
59	49.9	1966.1	98.11	58	87.3	64.7	5.65
22	37.9	2481.5	94.05	16	80.6	57.2	4.61
21	25.7	3389.3	87.11	54	33.5	131.9	4.42
45	19.9	4331.0	86.19	66	99.7	37.5	3.74
25	40.9	1733.1	70.88	76	81.0	43.4	3.51
60	25.8	2720.0	70.18	55	121.6	28.1	3.42
51	31.5	1936.5	61.00	68	109.1	18.6	2.03
9	32.3	1738.6	56.16	78	151.7	11.7	1.78
72	87.1	616.6	53.71	79	78.3	18.5	1.45
48	44.7	1163.1	51.99	15	124.8	7.6	0.95
46	24.7	1977.3	48.84	75	92.9	9.5	0.88
28	32.6	1349.1	43.98	69	161.1	2.8	0.46
63	72.7	587.5	42.71	86	82.7	2.8	0.24
38	85.3	383.2	32.68	20	26.1	2.4	0.06
70	62.6	518.3	32.45	77	67.3	0.6	0.04
35	71.1	430.0	30.58	53	51.5	0.6	0.03
84	84.2	259.5	21.85	36	34.1	0.3	0.01
33	61.9	351.0	21.73	44	18.1	0.4	0.01
71	101.9	207.5	21.14	23	-0.3	2078.1	-0.62
30	7.4	2694.0	19.94	24	-46.0	390.0	-17.94

†Sorting is by column 4, annual total cost.

‡MT: metric ton

Source: CBO(1985a)

Table 5: Minimum Δ with respect to each of the four distance functions, when each industry is taxed at the rate in column 2

$\Sigma(\tilde{p}_i - \hat{p}_i)^2$		
ID (1)	tax % (2)	Δ (3)
62	38.0	0.0402
37	24.8	0.0806
91	8.8	0.0838
98	16.8	0.0857
47	17.8	0.0874
93	24.2	0.0888
2	11.8	0.0894
22	29.4	0.0901
43	6.2	0.0920
17	11.2	0.0922
32	5.0	0.0922
13	3.6	0.0923
28	7.8	0.0930
92	7.6	0.0935
26	6.0	0.0937
45	5.6	0.0937
49	4.2	0.0942
9	4.8	0.0943
25	4.6	0.0945
64	5.4	0.0945
97	15.4	0.0945
39	5.6	0.0945
3	6.4	0.0945
42	3.0	0.0947
30	4.2	0.0947
57	4.6	0.0949
59	6.4	0.0950
18	3.2	0.0950
51	3.8	0.0951
46	2.6	0.0951
27	4.0	0.0952
current Δ =		0.0952

$\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert$		
ID (1)	tax % (2)	Δ (3)
62	37.6	1.026
93	21.6	1.073
98	10.6	1.086
91	5.8	1.090
43	7.4	1.142
2	10.0	1.146
22	21.2	1.149
37	24.6	1.177
13	4.8	1.179
32	5.2	1.184
92	19.6	1.192
47	17.2	1.197
26	12.2	1.204
25	13.6	1.216
64	15.8	1.217
17	8.8	1.218
57	16.0	1.232
39	19.6	1.234
3	24.4	1.239
42	6.0	1.252
28	7.6	1.257
45	5.4	1.261
49	3.8	1.270
9	4.8	1.271
97	32.2	1.272
18	6.8	1.274
59	5.4	1.277
80	3.2	1.279
46	2.2	1.282
51	2.2	1.283
95	16.6	1.283
27	3.8	1.284
current Δ =		1.286

$\Sigma(\tilde{p}_i - \hat{p}_i)^2 w_i$		
ID (1)	tax % (2)	Δ*10^-5 (3)
62	39.2	3.049
47	19.0	5.131
17	10.8	5.280
43	3.4	5.362
37	25.8	5.379
39	3.8	5.521
13	1.4	5.574
22	7.4	5.575
26	4.0	5.583
18	2.8	5.672
80	3.8	5.711
57	1.8	5.736
85	2.2	5.739
91	0.6	5.748
25	2.6	5.751
59	7.6	5.776
current Δ =		5.776

$\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert w_i$		
ID (1)	tax % (2)	Δ*10^-3 (3)
49	472.0	1.685
43	8.2	1.901
17	36.0	1.951
26	13.6	2.010
39	13.0	2.016
44	219.8	2.030
15	179.8	2.032
62	97.8	2.046
23	42.6	2.048
25	13.4	2.054
55	557.4	2.059
13	2.0	2.061
14	187.2	2.063
77	271.8	2.067
46	58.0	2.085
59	117.8	2.104
16	197.0	2.117
56	597.0	2.135
47	72.6	2.142
51	83.2	2.169
45	93.4	2.188
30	74.2	2.201
18	13.4	2.212
52	84.4	2.221
50	42.6	2.246
42	12.4	2.252
57	4.4	2.253
48	72.6	2.258
63	141.0	2.271
37	197.0	2.280
61	84.6	2.289
53	17.6	2.299
3	0.4	2.314
92	2.4	2.327
98	0.2	2.333
80	10.4	2.354
85	1.8	2.367
64	0.8	2.380
current Δ =		2.383

Note. This table lists only taxes on industries that can reduce Δ to less than the current Δ. An industry picked up by one function does not have to be picked up by any other distance function. $\Sigma(\tilde{p}_i - \hat{p}_i)^2$ represents function (15), the sum of non-weighted squares of differences between estimated prices and target prices. $\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert$ represents function (16), the sum of non-weighted absolute values of differences. $\Sigma(\tilde{p}_i - \hat{p}_i)^2 w_i$ represents function (17), the sum of squares of differences weighted by the share of output. $\Sigma\lvert\tilde{p}_i - \hat{p}_i\rvert w_i$ represents function (18), the sum of absolute values of differences weighted by the share of output.

Figure 1

With Constant Return to Scale and Perfect Competition, Consumers Benefit by Shaded Area

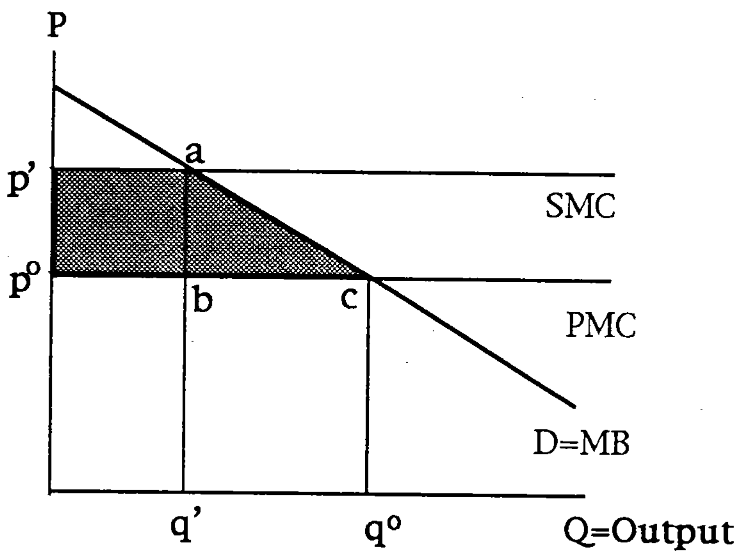

Figure 2

Without Constant Return to Scale,
Consumers Benefit by Shaded Area

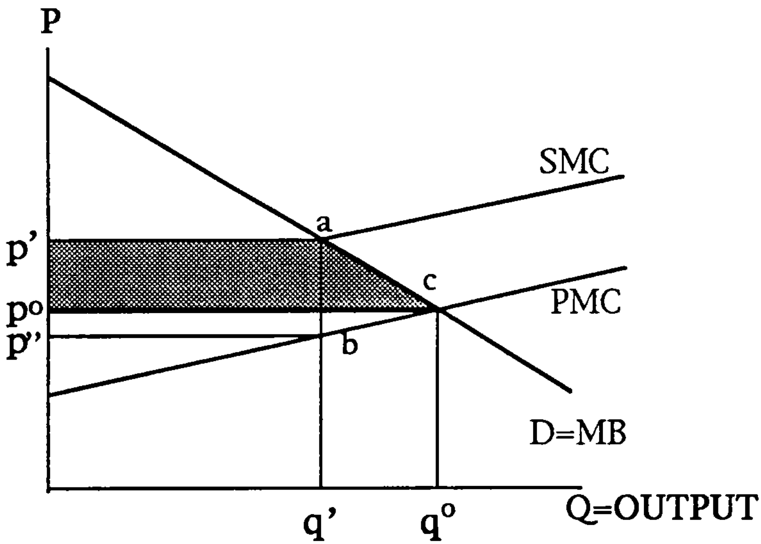

Figure 3

With Pure Monopoly, Consumers Benefit by Shaded Area

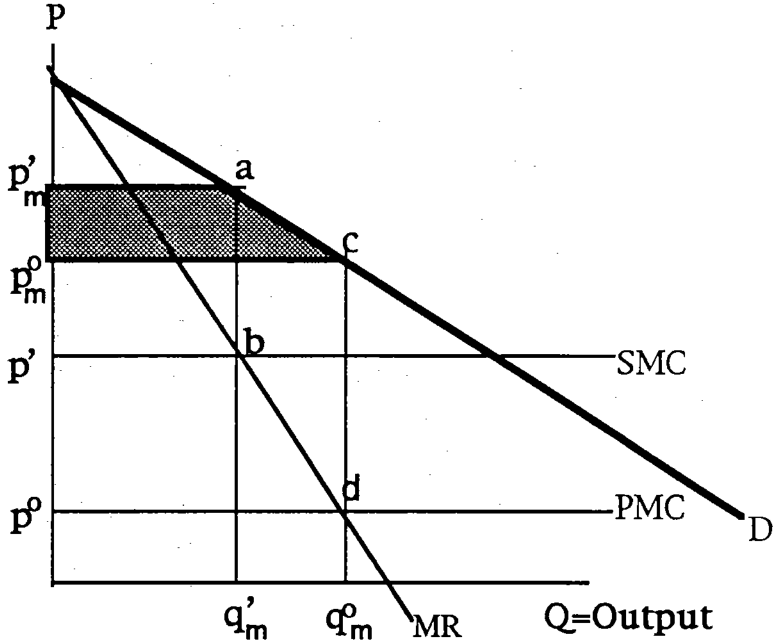

Figure 4: Prices under current taxes miss the target prices

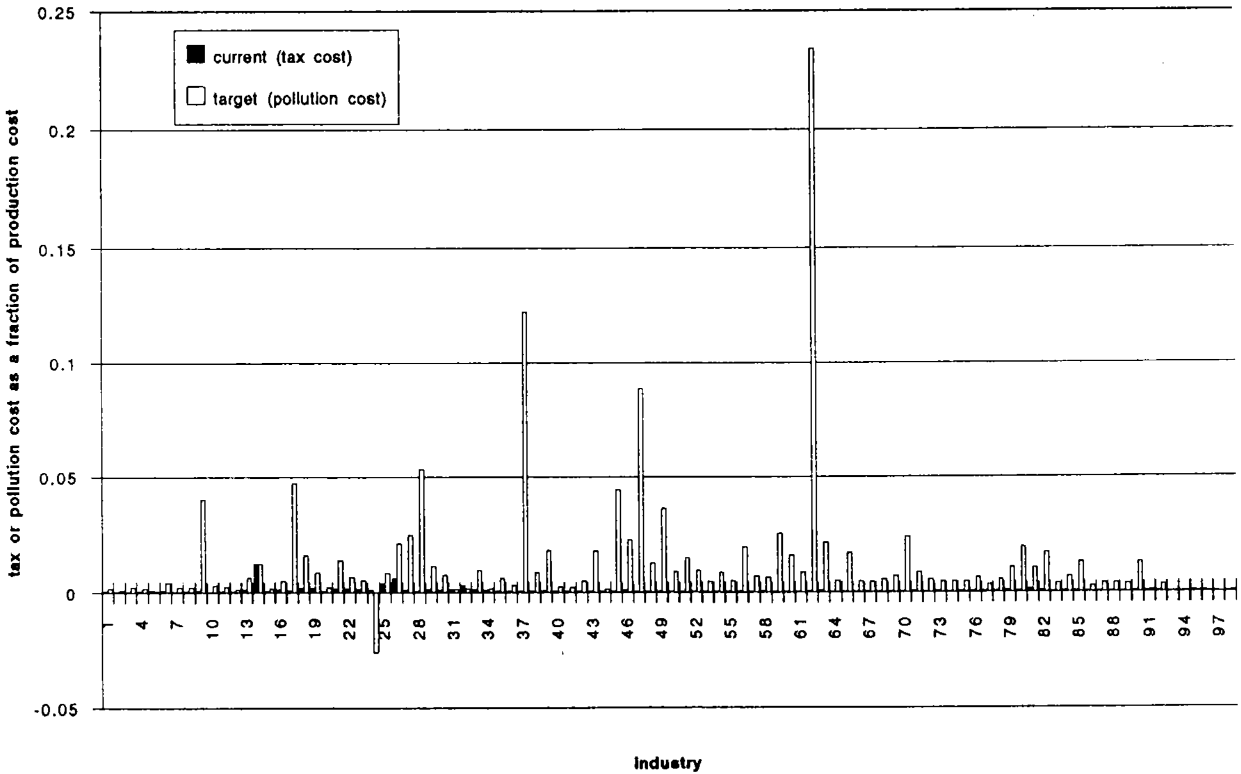

Figure 5: Prices with 4.4% corporate environmental tax, and the target prices

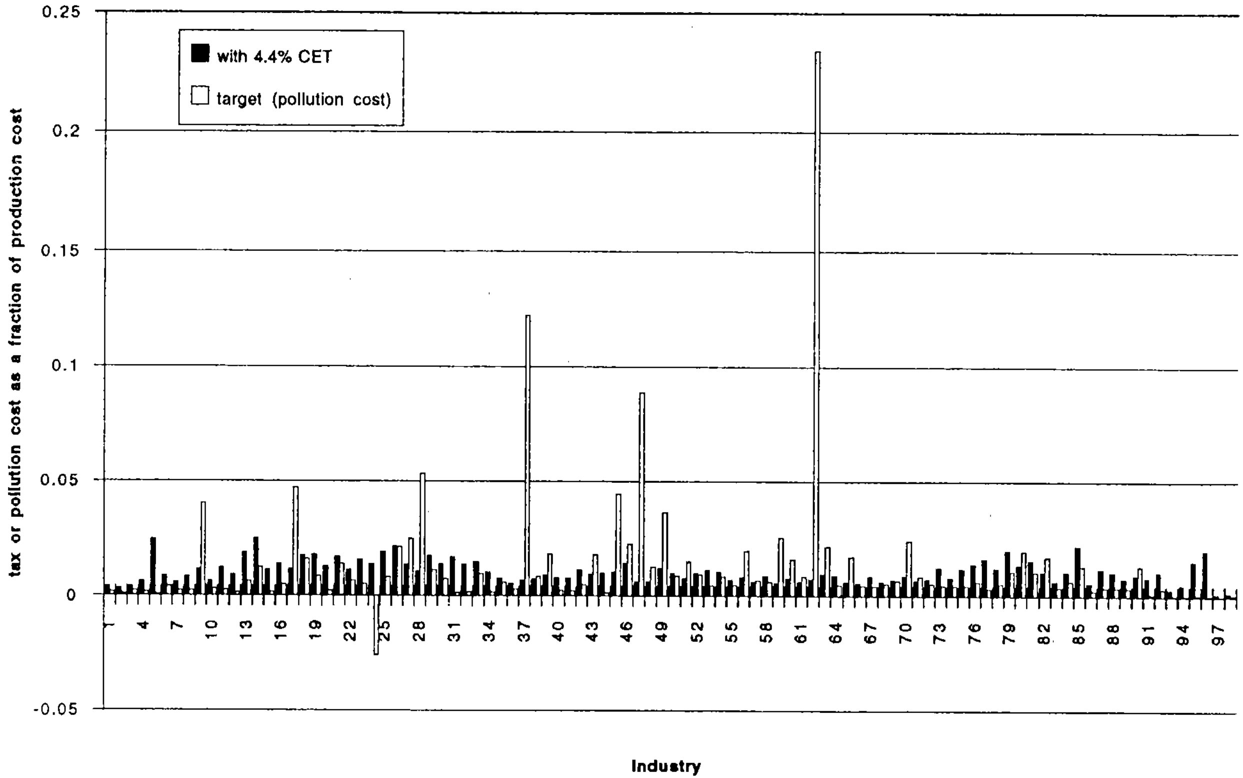

Figure 6: Prices with 1.2% corporate environmental tax, and the target prices

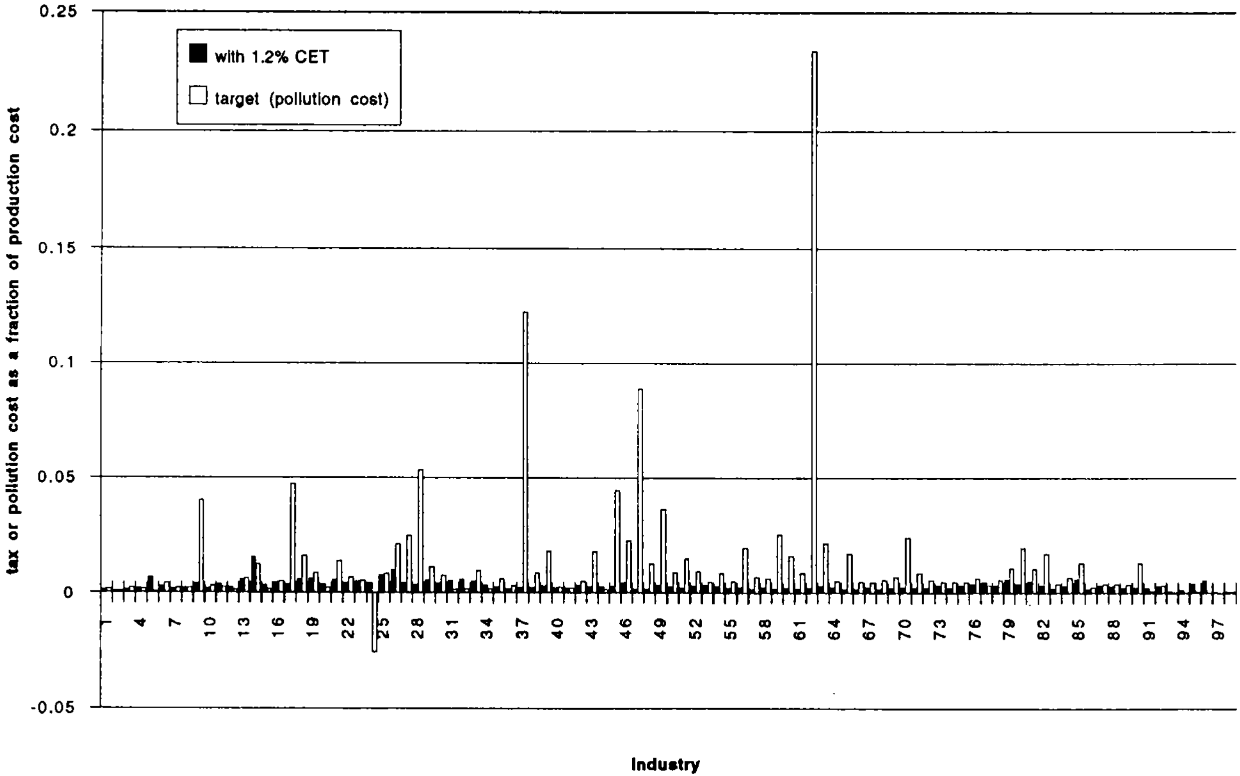

Figure 7: Prices with tax on inputs 62, 37, 47