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WHY HAVE SEPARATE ENVIRONMENTAL TAXES?

Don Fullerton

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ABSTRACT

Each environmental tax in the U.S. is designed to collect revenue for a trust fund used to clean up a particular pollution problem. Each might be intended to collect from a particular industry thought to be responsible for that pollution problem, but none represents a good example of an incentive-based tax designed to discourage the polluting activity itself.

A different tax for each trust fund means that each tax rate is typically less than one percent. But each separate tax has an extra cost of administration and compliance, since taxpayers must read another set of rules and fill out another set of forms. This paper provides evidence on compliance costs that are high relative to the small revenue from each separate tax. In addition, an input-output model is used to show how current U.S. environmental tax burdens are passed from taxed industries to all other industries. Thus the extra cost incurred to administer each separate tax achieves neither targeted incentives not targeted burdens.

Don Fullerton
Department of Economics
University of Texas at Austin
Austin, TX 78712-1173
and NBER

1. INTRODUCTION

Many economists and policymakers are beginning to discuss potential gains from better coordination of environmental policy and tax policy. If properly designed, certain taxes can help prevent environmental harm while raising revenue that can be used to reduce other distorting taxes, or to feed a trust fund for the clean-up of existing environmental problems. Yet the design of such taxes is difficult. Even without coordination, environmental policy and tax policy must each strike a balance among competing economic and political objectives. With attempts to coordinate these policies, the tradeoffs become all the more complicated.

This paper is concerned with the design of taxes that might coordinate environmental and tax policy, and with the tradeoff among three particular objectives. First, a tax might be designed to discourage an activity that causes environmental harm. A tax on vehicle emissions, for example, would provide incentives to reduce emissions by fixing the vehicle's pollution control equipment, scrapping old vehicles, driving less aggressively, or reducing total mileage.

Second, a tax might be designed to place its burden on those responsible for a particular environmental problem. This objective relates to fairness, rather than incentives. The tax on vehicle emissions would meet both objectives, because it would discourage the polluting activity while collecting from those responsible. But environmental taxes do not necessarily meet both objectives. The emissions tax may soon be feasible, but it is not yet in place. Meanwhile, the U.S. relies on a combination of other policies including a tax on gasoline. This tax does collect from those who drive vehicles and are thus responsible for the pollution, but it does not provide incentives to fix pollution control equipment or otherwise reduce emissions per mile driven.

Third, a tax might be designed to minimize administrative cost to the government and compliance cost imposed on taxpayers. The same example highlights the tradeoff among these objectives: a tax on vehicle emissions might have better incentives to reduce emissions, but it would be difficult and therefore costly to administer. The gasoline tax might provide the best balance among objectives, since it has some of the desired incentives to reduce driving, it places its burden on those who emit pollutants, and it is easily collected.

In discussing these three objectives, the paper will abstract from many other interesting problems and objectives of policy. Also, the paper will not attempt a comprehensive evaluation of all U.S. environmental taxes. Any tax may have environmental effects, and none can be evaluated fully in this limited space. Instead, the paper will use selected examples of the tradeoffs among these three objectives. The next section discusses the design of environmental taxes generally, including the tradeoff among many possible objectives. The following section provides evidence on administrative costs, and estimates some compliance costs. Later sections will review effects of some actual environmental taxes in the U.S., and a case study of an incentive-based tax that failed. The last section presents an input-output model and uses it to estimate the shifting of U.S. environmental tax burdens from taxed industries to other industries.

Any generalization might be considered adventurous, since each U.S. tax has somewhat different effects on incentives, burdens, and compliance costs. Nevertheless, three conclusions emerge from this analysis. First, in general, U.S. policy has *not* used "environmental taxes" for incentives to discourage pollution. The U.S. has no tax on vehicle emissions, no tax on smoke-stack emissions, and no tax on the generation or disposal of waste. Instead, actual policy has put great weight on the second objective, to collect from those responsible for pollution. Congress seems concerned not with incentives for future behavior, but with funding the cleaning up of *past* pollution at existing toxic waste sites, oil spills, and leaky underground storage tanks. The U.S. imposes "environmental" taxes on chemicals, petroleum, and other inputs to production. These taxes may collect from the industries responsible for contaminated sites, and they finance various trust funds for the clean-up those sites, but they do not discourage behavior that leads to contamination or spills. To put the point more strongly, these taxes apply to *goods* that are useful in production rather than to *bads* such as pollution. They may well distort incentives *away* from efficient methods of production, rather than improve incentives by discouraging pollution.

Second, these taxes raise the cost of production and thus raise equilibrium output prices. An incentive-based tax on smokestack emissions would raise the cost of producing certain goods, but then those goods are used as inputs to the production of other goods. The ultimate burden becomes diffuse. Similarly, actual U.S. taxes apply to goods like chemicals, petroleum, and coal that are inputs to virtually all other industries. Calculations below use an input-output model to find the effect of actual environmental taxes on 41 output prices. Taxes apply to 9 of the intermediate inputs, at rates up to 7 percent, but they raise the cost of production for all 41 outputs. Most prices rise by less than one percent, and the largest increase is 2 percent. Thus the ultimate burdens are similar to those of a broad-based tax. Separate environmental taxes are not effective at targetting burdens on those responsible for pollution, except to the extent that all of us are responsible. The objective of fairness may be equally met by broad-based taxes.

Third, the evidence on administrative and compliance cost strongly suggests economies of scale in the collection of revenue. Each tax requires its own set of forms, its own administrative structure, and its own calculation of the tax base for each taxpayer. Those calculations are the same whether the tax base is multiplied by a low tax rate or a high tax rate. Thus the compliance cost as a fraction of revenue will tend to be high at tax rates that are low. Yet each separate environmental tax in the U.S. collects revenue for a separate cleanup program that represents a very small fraction of the total federal budget. Each rate of tax is typically less than one percent. Thus these taxes have relatively high compliance cost per dollar of revenue.

When the three pieces of this puzzle come together, an interesting pattern emerges. A separate environmental tax might be effective at discouraging a particular polluting activity, even if it requires its own administrative structure and has a relatively high compliance cost per dollar of revenue. But actual environmental taxes do not follow that logic. Separate environmental taxes are used not for incentives, but to target burdens on particular industries thought to be responsible. Each tax funds the clean-up of a particular pollution problem, applies at a low rate, and has relatively high compliance cost. But burdens cannot be targetted. The same revenue could be collected, with the same diffuse burdens, using an existing broad-based tax instrument with much lower compliance cost per dollar of revenue. The analysis points towards better use of incentive-based environmental taxes, or the funding of cleanup programs using general revenues.

2. THE DESIGN OF ENVIRONMENTAL TAXES

Policymakers are torn by tradeoffs among competing policy objectives. This section briefly describes at least a dozen such objectives, though the rest of the paper concentrates on the first three of them. First, a tax can be used to increase economic efficiency by discouraging an activity that causes environmental harm. In theory, total welfare of society is maximized by continuing a production activity until social marginal benefit falls to the level of social marginal cost. If some pollutant generates external costs not recognized by the firm, then the activity may continue beyond that point, until marginal benefit falls to the level of purely private marginal cost. This behavior can be restrained either by traditional command and control regulations that tell the firm to cut back, or by incentive-based policies that induce the firm to cut back. As suggested by Pigou (1932), a tax on emissions can make the firm recognize the full social cost of its actions. Ideally, the Pigouvian tax would apply not to the output of the industry, but to the part of the production process that causes the pollution. For example, a tax on hazardous waste would provide incentives to change not just the input of chemicals, but the nature of their use and the generation of hazardous waste by-products. Such taxes raise the cost of production, and higher prices might discourage purchase of the output, but they also provides incentive for the firm to reduce the pollution per unit of output. Such taxes might improve upon command and control regulations by inducing firms to find the minimum cost method of controlling waste emissions: each firm can decide whether it is cheaper to scrap the old process for a new technology, switch inputs, buy control equipment, or pay the tax.

Thus the "polluter pays" can be interpreted as a principle of economic efficiency, where the objective of the tax is to collect a marginal price per unit of pollution. But it can also be interpreted as a principle of fairness, where the objective of the tax is to collect appropriate total amounts from the parties responsible for the pollution. A tax might be used to acheive this second objective without the first. An example is the U.S. tax on chemical feedstocks (intermediate inputs). This tax is devoted to the cleanup of abandoned contaminated sites under the Superfund program, and it may well collect from the firms responsible for that pollution, but this tax on the input of chemicals does not provide incentive to change the *use* of those chemicals, to reduce the generation of waste, or to dispose of that waste safely. It does not discourage the abandonment of contaminated sites.

The goal of fairness might also involve distributional effects more generally, including the ultimate burdens of the tax on different income groups.

A third goal is to minimize administrative costs to government and compliance costs to taxpayers. Increased complexity usually requires more instructions, more time filling out forms, and more difficult audits. Yet some complexity might be necessary to identify particular polluting activities. A tax on hazardous waste would better discourage polluting behavior, but taxes on chemical feedstocks and petroleum are probably easier to administer and still collect from the waste-generating firms. Another complication is that the administrative cost of using taxes to protect the environment really should be compared to the analagous administrative costs of using alternative command and control policies to regulate polluting behavior.

Some other objectives should at least be mentioned.[1] A fourth goal is to avoid problems of information and measurement. The ideal incentive-based tax rate would reflect the marginal external cost of pollution, but this cost is difficult to measure since it may require the probable number and cost of illnesses, the dollar value of lives lost, and aggregate willingness to pay for greater visibility. Yet actual environmental tax rates are not set on this basis at all. Each tax is set instead at a rate that will yield a pre-specified revenue for a trust fund. For example, Superfund taxes pay for the costs of cleaning up existing contaminated sites -- costs that bear no relation to the external cost of using more new chemicals or petroleum.

A fifth goal is the flexibility to adjust tax rules as information and measurement improve, or as the situation changes. On the other hand, a sixth goal is to provide business with a more certain set of tax rates, so as not to change the rules in the middle of the game. Seventh, the policy needs to reflect monitoring capabilities. A Pigouvian tax may require counting tons of emissions, whereas a design standard simply requires authorities to confirm the use of a particular kind of pollution control equipment. An eighth goal is political feasibility. A regulation can "guarantee" certain pollution controls, whereas a tax must rely on the theory that firms will be induced to cut pollution. Also, existing firms may provide more support for a plan to allocate tradeable permits than for a plant to tax on all emissions. A related objective, ninth, involves ethics. One view is is that pollution is a "crime against nature" that ought to be stigmatized by

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[1]A large literature discusses the choice among policy options. See Bohm and Russell (1985), Baumol and Oates (1988), Merrill and Rousso (1991), or Barthold (1994).

legal regulations rather than condoned by the mere payment of a tax. Tenth, policymakers must worry about the costs of transition to a new system of taxation, including unemployment, moving costs, and retraining. Yet another objective is to account for methods of avoidance or evasion. A tax applied to each unit of waste brought to a qualified disposal facility might be designed to reflect the social harm from that waste and to discourage generation of waste, but it might just shift disposal away from the qualified facilities and towards improper methods of disposal that can cause worse environmental harm.[2] Finally, the implementation of a Pigouvian tax might be complicated by the concern for other policy goals related to issues such as market structure, monopoly power, trade agreements, and international competitiveness.

No tax can meet all twelve of these objectives. It might be possible to identify certain reforms, however, that can achieve more of one objective without significant losses elsewhere. In particular, since existing U.S. environmental taxes are not designed for incentives anyway, an alternative broad-based tax may have the same diffuse burdens with less compliance cost.

3. ADMINISTRATIVE AND COMPLIANCE COST

The IRS budget is about $6 billion per year, which includes spending on equipment and rent as well as salaries of clerks, auditors, and lawyers. This administrative cost is less than 0.6 percent of total federal receipts ($1.09 trillion in 1992). Thus the U.S. is fairly efficient at collecting taxes. The IRS cannot break down their costs of collecting each tax.

The reason the U.S. government has relatively low collection cost is that it puts most of the cost on the taxpayers. The compliance cost to taxpayers includes not only the dollars paid to accountants and lawyers, but the value of all time spent keeping receipts, reading instructions, and filling out forms. For the individual income tax, Slemrod and Sorum (1984) estimate for 1982 that "between 1.8 and 2.1 billion hours of taxpayer time were spent on filing tax returns, and between $3.0 and $3.4 billion was spent on professional tax assistance." Taxpayer time is valued

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[2]In some cases, evasion is easy. A tanker truck filled with waste can enter a truck wash, get all the washer spray going, and then open the drain on the bottom of the truck. Another example is that waste oil can easily go undetected if dumped on roadbeds of railroad lines.

at the net wage rate to find that total compliance cost is five to seven percent of revenue. Thus the compliance cost of the income tax is ten times the administrative cost to the IRS.

3.1 Economies of Scale

Both logic and evidence suggest that many of these administrative and compliance costs are "fixed" costs of calculating the tax base, not marginal costs of collecting more revenue by raising the *rate* of tax on a given tax base. Compliance costs depend on the complexity and number of forms to be filed by taxpayers, just as administrative costs depend on the number of forms to be checked by the IRS. Under the income tax, different forms are required for itemized deductions, depreciation calculations, and each type of income such as interest, dividends, capital gains, rental income, and self-employment income. The last step is to multiply this tax base times a tax rate, or just look up the tax in a table provided by the IRS, a step that is equally simple whether that tax rate is one percent or 30 percent. Thus the technology of tax collections exhibits economies of scale. The administrative cost or compliance cost as a fraction of tax revenue is expected to fall as the tax rate and revenue become larger.

The same economies hold for excise taxes. When the United Kingdom increased the value added tax rate from 8 to 15 percent in 1979, for example, Sandford et al (1989) found that "over the next few years the [administrative] cost:revenue ratio in the collection of VAT fell from 2 percent to one percent mainly, though not solely, because of the increase in rate" (p.20).

Sandford et al find further evidence of economies of scale by looking at firms of different sizes. For 1986-87 in the U.K., the cost of complying with the VAT as a percent of the tax base is smaller for businesses that are larger, as measured either by the tax base or by the number of employees (p.142). Similar results were found for the goods and services tax (GST) in Canada, by Plamondon and Associates (1993), and for the corporation income tax in the U.S. by Slemrod and Blumenthal (1993).[3] Although this type of scale economy pertains to firm size, rather than

[3]Slemrod and Blumenthal (1993) say that their "tables 10 through 15 suggest that, in general, compliance costs rise less than proportionately with firm size, so that average costs per unit of size, however measured, are lower for larger firms.... The findings of economies of scale in tax compliance costs is common in studies across countries and across types of tax" (p. 6).

tax rate, the implication still is that compliance cost includes a fixed annual amount that depends on the number and complexity of forms used to calculate the tax base.

If the only goal were to raise a small additional amount of revenue for a trust fund, this analysis suggests a small increase in a pre-existing excise tax rate, corporate income tax rate, or even personal income tax rates. If a special tax must be introduced, the revenue would be collected most efficiently with a single tax rate on a relatively simple tax base.

3.2 An Estimate of Compliance Cost for the Corporate Environmental Tax

Superfund's corporate environmental tax (CET) is not an excise tax at all. It applies at a 0.12 percent rate on a measure of income that is related to the alternative minimum tax (AMT), regardless of whether that firm is actually subject to the AMT.[4] Revenue is about a half a billion dollars, but compliance is complicated.

To calculate the AMT, the firm starts with its regular taxable income and adds back net operating loss deductions, "adjustments," and "preference" items such as interest from certain tax-exempt bonds. The "adjustments" include the difference between depreciation according to regular tax schedules and depreciation according to AMT rules. Thus, for each asset it purchases, the firm must keep track of one depreciation schedule for book purposes, another for the regular tax, and a third for the AMT. Also, deductions are cut back for mining costs, intangible drilling costs, and pollution control facilities (see Lyon, 1991, pp. 51-82). Then the AMT requires an additional calculation of profits, termed Adjusted Current Earnings (ACE).

The firm calculates regular tax as 35 percent of corporate taxable income, and then it calculates tentative minimum tax as 20 percent of AMTI -- a broader definition of income. It pays AMT equal to the excess of tentative minimum tax over regular tax, if any.

Regardless of whether the firm pays AMT, the corporate environmental tax (CET) applies at a 0.12 percent rate to "modified" AMTI in excess of $2 million, where AMTI is modified to

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[4]The alternative minimum tax (AMT) was created in 1986 to ensure that taxpayers with substantial incomes could not avoid paying taxes through "excessive" use of deductions, tax credits, and other exclusions permitted under the law.

disallow deductions for net operating losses and for the CET itself.

If all firms had to calculate AMTI anyway, then the CET would not introduce much additional compliance cost. Of the 12,199 firms that paid CET in 1990, however, 8,584 (70 percent) did *not* pay AMT.[5] The additional costs to these firms of complying with the CET can be substantial, if they are anything like the cost of complying with the AMT estimated by Slemrod and Blumenthal (1993). Those authors survey 365 large corporations and find that their average cost of corporate income tax compliance is $1.57 million (p.5). Using the 365 observations, they regress compliance cost on certain firm characteristics and find that:

> Being subject to the alternative minimum tax (AMT) adds 16.9 percent; this is true even though all but three of the firms report that they must *calculate* the alternative minimum tax liability. This result implies that those firms that suspect that they will actually have AMT liability devote more resources to its calculation and planning implications (pp. 7-8).

In other words, almost all firms make initial calculations to determine *whether* they are subject to the AMT, but the extra 16.9 percent of compliance cost is incurred only by firms that really *are* subject to AMT. Presumably they review calculations carefully and undertake more tax planning.[6] This additional compliance cost is 16.9 percent of $1.57 million, or $265,330 per firm. This figure is used by Probst et al (1995) to provide a rough estimate of CET compliance costs.

First, however, consider the Slemrod and Blumenthal estimates. The $1.57 million of compliance cost seems large, but they look only at very large firms. In fact, 98 of their 365 firms are in the Fortune 500 largest industrial firms in the United States. For these large firms, the estimated compliance cost is a reasonable 3 percent of total taxes paid. Second, Slemrod and Blumenthal find that AMT calculations cost 17 percent more. This figure seems *low*, if anything, since the AMT is a parallel tax system that essentially doubles the number of calculations necessary to obtain taxable income, allowable deductions, and tax due. Thus the $265,330 is a very believable cost of AMT compliance for these firms.

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[5]Phone conversation with Patty Treubert, IRS, Statistics of Income Division, in May 1994.

[6]The regression results may also reflect greater complexity of AMT firms.

Third, consider what the cost of AMT compliance indicates about the cost of CET compliance. All large firms perform rough calculations to determine AMT liability, so the $265,330 represents the incremental cost of actually having to pay AMT. The same increment would represent the cost of having to pay CET, if the calculations are performed properly, since the same tax base is used for both. On the other hand, compliance costs include tax planning costs which may increase with the tax rate. In other words, firms may expend more effort to reduce AMT at the 20 percent rate than to reduce CET at the 0.12 percent rate.

Fourth, consider whether the Slemrod and Blumenthal firms are representative of CET firms. The surveyed firms are large, but so are CET firms, since the CET applies only to the extent that AMTI exceeds two million dollars. Of 3.7 million corporate tax returns in 1990, the IRS reports that only 5,589 (0.15 percent) are what they call "giants," firms with more than $250 million of assets. Of 32,462 AMT firms, however, 1,324 (4 percent) are "giants." Even more striking is that 3,131 of the 12,199 CET firms--a full 25 percent--are giants.[7]

Finally, consider which of these firms could be said to incur the extra $265,330 compliance cost. Of the 8,584 firms that pay CET but not AMT, the IRS reports that 1,952 (23 percent) are giants. If the $265,330 cost applies only to these 1,952 "giants" that pay CET and not AMT, the compliance cost would be $518 million. This compliance cost is 100 percent of total CET revenue.[8] This estimate is meant to be conservative, since it totally ignores compliance cost for the (12,199-1,952 =) 10,247 firms that are not giants or that already pay AMT.[9]

Even this estimate may seem implausibly large, but note that the $265,330 compliance cost represents only the annual cost of one accountant and one tax lawyer, a moderate allocation

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[7]These figures all were reported in a phone conversation by Patty Treubert, IRS, Statistics of Income Division, in May of 1994.

[8]Others have suggested that "the cost of computing the CET could be greater than the current tax liability" for some companies. See Price Waterhouse (1992), p.47.

[9]The Slemrod and Blumenthal firms may be even larger, on average, than these 1,952 giants. Micro data is not available to make use of the estimated coefficient on size. The $265,330 estimate may be a bit high even for these 1,952 firms, but this bias is probably more than offset by ignoring compliance cost of the other 10,247 firms on the CET.

of personnel for one of these giant corporations. This cost is attributed only to the largest 1,952 of the 12,199 CET firms. Instead, the same total estimated compliance cost ($518 million) can be expressed as an average of $42,462 for all of the 12,199 CET firms. The problem is not that this compliance cost is so large, but that the revenue is so small -- also only $42,462 per firm.[10]

This tax was not designed to discourage polluting activities, nor to target its burden. It is just meant to raise some money for the cleanup of contaminated sites under Superfund. But an additional collection mechanism is not necessary to raise some money for cleanup.

4. SOME ACTUAL ENVIRONMENTAL TAXES

The IRS Statistics of Income identifes four "environmental" taxes, on: (1) petroleum, for the Oil Spill Liability Trust Fund (OSLTF) and Superfund; (2) chemical feedstocks, for Superfund; (3) ozone-depleting chemicals, for the general fund; and (4) motor fuels, for the Leaky Underground Storage Tank (LUST) fund.[11] The top panel of Table 1 summarizes the rates and revenues from some components of these explicitly environmental taxes. Each is further discussed below. Then the bottom panel of Table 1 summarizes some other federal excise taxes that are likely to have environmental effects, such as taxes on coal, tires, gasoline, trucks and trailers, gas guzzlers, and transportation. These taxes probably discourage the use of fossil fuels that cause air pollution and global warming, but they are not labelled as environmental taxes because they do not feed a trust fund used to clean up the environment.

This list is only partial. Barthold (1994) provides a useful table of 51 federal tax code provisions that might affect the environment, including other excise taxes as well as federal income tax provisions such as credits for non-conventional fuels, reforestation, and closed-loop biomass production. The income tax also affects the environment through its treatment of

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[10]The CET is complex, but at least it uses the existing definition of AMTI. Some proposed alternatives would have invented a whole new tax base.

[11]The IRS lists many excise taxes that might affect the environment, like the gasoline tax for the Highway Trust Fund, but the category for "environmental" excise taxes includes only the four listed here, as discussed by Davie (1995) and Poterba and Rotemberg (1995).

commuting expenses, depletion allowances, intangible drilling expenses, mine exploration expenses, pollution control equipment, and capital gains from timber sales.[12] Analysis here is limited to the excise taxes listed in Table 1.

4.1 Petroleum Tax

An oil refiner is required to pay tax when domestic crude petroleum is received at a U.S. refinery, and an importer must pay tax when crude oil and refined petroleum products enter the U.S. Table 1 shows that in 1992 the Oil Spill Liability Trust Fund (OSLTF) received 5 cents per barrel, and the Hazardous Substance Superfund received 9.7 cents per barrel, so the combined tax on crude petroleum was 14.7 cents per barrel. At a price of about $20 per barrel, crude oil was effectively taxed at a rate of about 0.7 or 0.8 percent. The combined tax collected $827 million in 1992, which is only .076 percent of federal receipts ($1.09 trillion in 1992).[13]

This tax is small, but its operation is simple. Table 1 shows that it applies to only 341 firms. The last column divides tax revenue by the number of taxpaying firms, as a very rough indicator of compliance cost efficiency. For the Superfund tax on petroleum, the compliance cost per firm must be much less than the average revenue of $1.6 million per firm.

The revenue is used to clean up toxic waste, and Congress attempted to target the burden on those responsible. For the initial legislation in 1980, a survey of the chemical composition of hazardous waste sites was used to determine that 15 percent was derived from petroleum, 65 percent from petrochemicals, and 20 percent from inorganic substances. The total revenue requirement was divided in these proportions, and then the projected size of each tax base was

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[12]Barthold also describes several reasons for separate environmental taxes. First, a Pigouvian tax would discourage pollution. Second, the benefit principle suggests a "user fee" or tax that reflects benefits from using a public environmental resource. Third, a tax can represent a mandated "insurance premium" for risk pooling, such as the tax on petroleum that is used to clean up oil spills. A problem is that oil companies cannot draw on this fund in case of accident; it is only for costs that cannot be recovered from liable firms.

[13]The oil spill portion of the tax was suspended on July 1, 1993 (because the trust fund achieved its target of $1 billion), and it expired December 31, 1994. The remaining 9.7 cent Superfund tax represents less than one-half of one percent of the petroleum price.

used to determine the tax rate that would collect the desired revenue from each source.[14]

This rationale has a number of problems. First, even if this tax applies to the responsible firms, it cannot apply to the managers or shareholders responsible for this past pollution, since those individuals have long since changed jobs or sold their stock in the company. The burden of the tax could at best apply to new managers and shareholders who had nothing to do with the existing abandoned contaminated sites. Second, even if the legislated burdens on these firms are passed onto customers through higher prices, the customers may not be the same individuals who benefited from artificially low prices in the past. Third, the tax does nothing to discourage the abandonment of contaminated sites. It applies to petroleum as an input to production, not any waste by-product that gives rise to external cost. Other environmental regulations are designed to control the handling of waste from production processes that use petroleum. Similarly, as noted by Barthold (1994), the OSLTF tax on petroleum did not apply to oil spills or to behavior that might cause spills. It applied at the same rate to all oil, whether transported by pipeline, in single-hulled tankers, or in double-hulled tankers that are more difficult to rupture.

The petroleum tax might have some incentive effects that are favorable to the environment if it discourages the use of petroleum that is correlated to the burning of petroleum-based fuels or the runoff from petroleum-based fertilizers. But these goals could be better achieved by taxes on the appropriate fuels and fertilizers, if not directly on the emissions and the runoff.

4.2 Chemical Feedstock Taxes

Another federal excise tax is imposed on the sale or use of 42 organic and inorganic chemical feedstocks (intermediate inputs), whether domestic or imported. The revenue is devoted to Superfund. The tax rates were originally set in 1980 at $4.87 per ton for organic chemicals and at similar rates per ton for inorganic chemicals.[15] Since then, individual rates have been modified.

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[14]See the July 11, 1980, report of the Senate Committee on Environment and Public Works, regarding S. 1480, as described in Price Waterhouse (1992) Appendix A, note 23.

[15]Inorganic chemicals are taxed at $0.17 per ton plus $4.28 per ton times the portion of molecular weight deemed to be attributable to hazardous elements. The total tax rate was limited to 2 percent of wholesale price in 1980. See Price Waterhouse (1992), Appendix A.

Whereas the petroleum tax collected $553 million with a single rate on one commodity, Table 1 shows that the chemical feedstock taxes collected $252 million using 42 rates on 42 different commodities.[16] The complications are illustrated by the fact that a *different* set of chemicals is exempt under *each* of the following circumstances: if used in the manufacture of certain motor fuels; if used in making certain fertilizer; if produced as a by-product of air pollution control devices; if existing only temporarily in the smelting or refining of nontaxed chemicals; if coal-derived feedstocks; if a separated isomer of xylene; if recovered from certain recycling processes; if used to produce a qualified animal feed substance; if part of an intermediate hydrocarbon stream; or if exported (Commerce Clearing House, 1995, pp. 210-213).

In 1986, to avoid putting domestic producers at a competitive disadvantage, Congress added taxes on the import of 50 chemical substances produced using chemical feedstocks that are taxed in the United States. The rate on each of these substances is meant to reflect the tax that would have been paid on the chemical feedstocks used in its production. This law also directs the Secretary of the Treasury to augment this list with additional substances demonstrated to contain taxed chemicals that constitute 50 percent of the product by weight or by value. Since that time, at least 77 additional imported chemical substances have been added to the list. Despite imposing 127 different tax rates on 127 different imported chemical substances, these taxes together collected only $16.5 million in 1992, as shown in Table 1. This amount is about one percent of total Superfund tax, which itself is about 0.1 percent of total federal revenue.

If this tax had any benefit in terms of revenue or competitiveness, that benefit is swamped by administrative complexity. Because the chemical feedstock tax does not apply to exports, the IRS must establish procedures to refund the right amount of tax on an export produced using the taxed input. Then the IRS must continually consider petitions to add to the list, from exporters

[16]Several of the 42 rates are the same. All excise taxes appear on IRS Form 720 with one set of instructions, and one line for "chemicals," but the individual chemicals are listed on Form 6627 for "environmental taxes." A firm that must pay tax on two of these commodities clearly incurs less than twice the compliance cost of a firm that must pay tax on one. The main problem with taxing any additional commodity is that it may increase the number of firms that must file the forms. The IRS estimates the average firm's time requirements for recordkeeping (25 hours and 21 minutes), learning about the forms (2 hr., 26 min.), and preparing forms (8 hr., 52 min.).

who want refunds, and from others who want taxes on imported goods with which they compete.

The original motivation for these taxes was related to Superfund sites contaminated not by these chemicals themselves, but with toxic waste by-products that were generated by the use of these chemicals in complex compound forms (Fullerton and Tsang, 1993). Toxicity depends on what the firms do with the chemicals.

4.3 Ozone-Depleting Chemicals

The Montreal Protocol is an international agreement to phase out the use of halons and choloroflourocarbons (CFCs) that deplete the layer of stratospheric ozone protecting the Earth from harmful ultraviolet rays of the sun. Halons are used in fire extinguishers, and CFCs are used in air conditioners. The agreement sets phased quantity restrictions and lets individual nations decide how to meet them. The U.S. employs a combination of quantity regulations and taxes. The tax rate on each chemical is determined by a base tax amount (which started at $1.37 per pound in 1989) times an "ozone-depleting factor" (which was set at 1.0 for CFC-12, and which varies from 0.1 for Methyl Chloroform to 10.0 for Halon-1301). The number of taxed chemicals has grown to twenty, and the initial base tax amount has grown to $5.35 per pound in 1995. It will increase by another $.45 per pound every year.

This tax is not retrospective like other environmental taxes that finance a cleanup fund by collecting from those responsible for some past pollution problem. This tax does not feed a trust fund. It is prospective since it helps prevent further harm by reducing the future use of ozone-depleting chemicals. It applies fairly closely to the activity causing environmental harm, and it even applies at a rate that varies with the degree of environmental harm.

Yet Congress did not intend to use incentives for the environment. Instead, quantity restrictions on manufacturers were designed to meet the quantity targets in the Montreal Protocol. Congress then noticed that quantity restrictions can lead to monopoly profits. The tax rate was set equal to the expected difference between the new equilibrium price and the cost of production (Merrill and Rousso, 1991). In other words, this tax was enacted as a windfall-profits tax rather than as a Pigouvian tax. Congress was concerned with fairness and revenue, not incentives.

Producers reacted by cutting production below the levels mandated by the Montreal Protocol.[17] Since the quantity restriction is not binding, the tax unintentionally became the operational tool for reducing use of ozone-depleting chemicals.[18]

Any time a tax is imposed on a particular commodity, or in this case twenty, Congress has to worry about several issues that complicate the operation of the tax. First, rules and exemptions must be specified for each chemical. Second, the tax is imposed on manufacturers rather than the more numerous purchasers of these chemicals, but then the imposition of the tax can be avoided by selling off inventories in anticipation of the effective date. To prevent this transitional problem, Congress often imposes a special tax on floor stocks held by purchasers on the date such a tax is enacted or increased. Table 1 shows that the tax on floor stocks of ozone-depleting chemicals raised only $9.9 million in 1992, but applied to 1440 firms, so the average is only $6,900 per taxpayer.[19] The tax on floor stocks is shown only for ozone-depleting chemicals, in Table 1, but similar rules have applied to the imposition of taxes on virtually any kind of commodity.

Third, Congress is concerned with international competitiveness, and they feel compelled to tax each import at a rate that reflects the tax that would have been paid on the input to its production if it had been produced in the United States (Davie, 1995). The Superfund tax on imported chemical substances is described above, but a similar logic applies to ozone-depleting chemicals. Poterba and Rotemberg (1995) analyze the logic of this extra corrective tax, and show that it is impossible to implement in the common case where final goods are produced as joint

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[17]Barthold (1994) considers the case of ozone-depleting chemicals in great detail. He points out that the quantity control could be viewed as a "backstop that is reassuring to those who doubt the efficacy of the price system" (p. 135).

[18]Other aspects of the tax are not ideal for incentives. As just described, the tax rate was not set by looking at the environmental damage per unit of chemical. Also, the tax applies to production and use of these chemicals, whereas environmental damage occurs only upon their release into the atmosphere (Barthold, 1994). Halons are never released from fire extinguishers that are never used, and CFC's are not released from air conditioners if they are properly recaptured for later use. For this reason Bohm (1981) has suggested the use of a deposit-refund system that would rebate the tax on CFC's that are captured and returned.

[19]Though their own revenue is small, floor stock taxes may prevent the loss of excise tax revenues from manufacturers selling more inventories prior to the effective date.

products. The point here is that even if imperfect rules are implemented, using arbitrary assumptions about foreign production, they are bound to be complicated.

Finally, some of these complications can be avoided by ignoring small amounts, but Congress prohibited the Treasury from creating *de minimus* exemptions for electronics (Barthold, 1994). Thus the tax on import of goods produced using ozone-depleting chemicals is most often below 1 percent and is only 0.03 percent for fax machines, camcorders, and radios (Davie, 1995).

4.4 Motor Fuels

The fourth and final explicit environmental tax is a tiny $.001 per gallon tax on gasoline and other motor fuels that finances the trust fund used to clean up leaky underground storage tanks for which no solvent owner can be found. Fortunately, this small tax is attached to other more substantial taxes on gasoline and other motor fuels. The overall tax rate on gasoline is now $.184 per gallon, and the rate on diesel fuel is $.244 per gallon. Substitute fuels such as gasohol are taxed at lower rates, to encourage conservation of fossil fuels.

The gasoline tax is about the best available example of an incentive-based environmental tax (even though it is not called an environmental tax because it does not finance a cleanup program). Gasoline is a well-defined commodity to tax, and the revenue is substantial. This tax collected almost $15 billion in 1992, as shown in Table 1. It has incentive effects favorable to the environment since it might help conserve energy and improve air quality.

It is still a highly imperfect example, however. Its original intent was not as an incentive-based tax but as a user fee, to collect from those who benefit from public spending on highways. Most of it still finances the Highway Trust Fund, used for highway construction. Its incentives are weaker than one might think. Environmental damages result from emissions, and gasoline is only weakly correlated to emissions. Walls and Hanson (1995) describe how emission rates vary greatly across vehicle age, vehicle maintenance, and styles of driving. In a study of a scrappage program, Alberini et al (1994) find that pre-1980 vehicles currently have an average tailpipe hydrocarbon emission rate (6.6 grams/mile) that is 26 times the current new car standard (0.25 grams/mile). Even a relatively new car might have many times its original emission rate if its pollution control equipment is broken. Because of emissions from cold start-ups, Burmich (1989) finds that a 5 mile trip has almost three times the emissions per mile as a 20 mile trip at the same speed. Sierra Research (1994) finds that a car driven aggressively has a carbon monoxide emission rate (39 grams/mile) that is almost twenty times higher than when driven normally (2.2 grams/mile). The gasoline tax does not have incentives to scrap high-emission cars, fix broken emission equipment, or drive less aggressively.

Finally, some peculiar exemptions add considerable unnecessary complexity. Since it is a fee on users of highways, the special motor fuels tax (even the leaky underground storage tank portion) does not apply to: "off-highway business use" such as fisheries and whaling business, but "off-highway use" does not include motorboats or diesel-powered trains; use in farming; sales to museums that operate exclusively for the care of World War II aircraft; sales to state and local governments and to Indian tribal governments; certain diplomatic uses; sales to nonprofit educational institutions; and, use in a helicopter if for the exploration or development of minerals, oil, or gas, or in logging operations, or emergency medical services, unless the helicopter takes off or lands at an airport eligible for federal assistance (Commerce Clearing House, 1995, pp. 50-3). These exemptions are designed to target burdens, not environmental incentives.

4.5 Other Implicit Environmental Taxes

Besides those four explicit environmental taxes, Table 1 lists a number of other taxes likely to have environmental effects. These taxes might feed a trust fund (but not for a cleanup program like the explicit environmental taxes). The tax rates on coal in 1995 are the same as in 1992, shown in Table 1, when the combined revenue was $630 million (0.06 percent of total federal receipts). This tax might discourage some use of fossil fuels, but it was designed to place a burden on those who benefit from the use of the Black Lung Disability Trust Fund.

The small ($43 million/year) tax on pistols and revolvers might be called environmental, since it feeds the Wildlife Restoration Account, but it was designed as a user fee on those who benefit from that account. To the extent that it discourages the use of guns, it might be said to correct a negative externality. The tax code includes a plethora of other excise taxes that might discourage driving and other use of fossil fuels, such as taxes on tires, on heavy trucks and trailers, on air transportation of persons and property, and on vehicles shown to have low mileage per gallon ("gas guzzlers"). A few of these taxes are listed in Table 1. Section 6 considers whether the many separate taxes have any separate effects on tax burdens.

5. A CASE STUDY OF AN INCENTIVE-BASED TAX THAT FAILED

The incentive-based tax inevitably conflicts with other goals of policymakers. Consider a waste-end tax. First, the waste reduction itself conflicts with the tax revenue goal, since it erodes the tax base and reduces revenue. For this reason, waste reduction has most often been *omitted* from any list of goals for actual waste-end taxes in the past.

Second, the waste-end tax may conflict with the goal of fairness if it is used to clean up an existing contaminated site, since it collects from generators of new waste, and from those who use proper (taxable) disposal methods, not from those who generated the past waste that was improperly handled at the existing contaminated site.

Third, a waste-end tax may conflict with the goal of minimizing administrative cost. It may be particularly difficult to implement, for lack of data on the number of hazardous waste generators or the amount of each type of waste generated.[20] It may be difficult to administer and to enforce, because of easy opportunities for avoidance. Firms may use cheap on-site disposal methods that are hard to capture within the purview of the tax, and they might use other methods that are outright illegal such as midnight dumping. The usual tax administration and compliance cost is augmented by significant *non*-compliance costs.[21]

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[20]See Carlson and Bausell (1987). They also evaluate several waste-end tax options. McNeil and Foshee (1988) compare a tax on waste disposal to a tax on waste generation.

[21]These non-compliance costs can be reduced by replacing the waste-end tax with a "deposit-refund" system. Bohm (1981) and Fullerton and Kinnaman (1995) describe such a system. First, it would collect tax on each firm's purchase of any substance that is potentially polluting, at a rate that reflects the external cost of illegal disposal of that substance. Second, it would then rebate those taxes according to the amounts of those substances that exit the firm via sales of final products, leaving no tax on substances that do not appear as waste. Third, it would rebate *part* of the original tax on any item that exits the firm via qualified disposal methods. The

Consider the reasoning behind the federal waste-end tax originally enacted in 1980, and behind its repeal in 1986.[22] The 1980 legislation not only established the Hazardous Substance Response Trust Fund (later known as Superfund) in order to deal with contaminated sites, but it also established the Post-Closure Liability Trust Fund (PCLTF) in order to ensure continued long term monitoring and care at other closed hazardous waste disposal facilities. To qualify for this program, a facility must receive a permit under the Resource Conservation and Recovery Act (RCRA), operate in compliance with RCRA, continue monitoring for five years after closing, and demonstrate no substantial likelihood of any future release of hazardous substances. After the five year period, the federal government would assume any future liability (including third party claims, not covered under Superfund). The PCLTF was financed by a tax on hazardous waste that would remain at qualified facilities, at a rate of $2.13 per dry-weight ton. This tax would not be imposed during any year in which the balance in the fund exceeded $200 million.

The PCLTF was intended to encourage firms to comply with RCRA, and not to abandon sites upon closure. The fund would help avoid future health hazards, increase the chances of detecting releases promptly, and ensure that funds would be available to pay remaining claims (U.S. Environmental Protection Agency, 1985, p.13). The tax, of course, was intended to finance the fund. It follows the "polluter pays" principle by collecting from firms that generate the wastes that entail the risk of future health or property damage. Note, however, that this list of goals omits any mention of using the tax to reduce the generation of such waste.

This fund and waste-end tax had a long list of problems that let to its repeal. First, the legislation never defined a "dry-weight ton." Presumably the intent was to exclude the water component of different wastes in order to make them comparable, but it certainly left an administrative complexity. Second, the tax base excluded a lot of waste that is never sent to a

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part of the tax that is not rebated could reflect the social external cost of disposal that takes place even by qualified methods at qualified sites. The entire tax would remain on substances appearing neither in sales nor in qualified disposal methods -- presumably illegal disposal. Such systems may be difficult to implement, but they are not as difficult as taxing illegal disposal directly.

[22]The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was in 1980, and Superfund Amendments and Reauthorization Act (SARA) in 1986.

qualified facility but is instead managed on site.[23] Third, the tax and the fund applied to land-disposal facilities such as a landfill or surface impoundment. To the extent that the fund helped insure firms undertaking land disposal, it conflicted with the stated goal of the Hazardous and Solid Waste Amendments of 1984 (HSWA) to minimize the disposal of hazardous wastes in the land. Conversely, to the extent that HSWA discourages land disposal, it significantly reduces the revenue from this tax on land disposal. Besides, incentives for care are adversely affected by taking liability away from the original owner or operator of the facility.

Finally, the $200 million limit did not allow enough funds to cover likely liability claims. The EPA (1985) estimated that the fund would have less than a ten percent chance of remaining in positive balance after 100 years. If the $200 million limit were removed, and if the rate were increased over time to account for inflation, the fund would have a 90 percent chance of a positive balance after 100 years.

Faced with a revenue shortfall for a fund that contradicted a national policy to discourage land disposal of hazardous waste, Congress in 1986 decided to repeal the PCLTF and to refund all amounts that had been collected (see U.S. General Accounting Office, 1990).

6. THE SHIFTING OF ENVIRONMENTAL TAX BURDENS

Congress can decide who is legally liable to pay a tax, but it cannot legislate the ultimate distribution of burden. A tax on one good may reverberate through the economy in such a way that other prices are affected. An untaxed good may end up with a higher price, and anyone who buys it bears a burden.[24] This section describes calculations using an input-output model that accounts for some of these indirect effects. Since each industry purchases intermediate inputs that

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[23]Environmental Information (1993) estimates that 95 percent of hazardous-waste-generating firms rely on off-site facilities, but that 95.4 percent of hazardous waste volumes were managed *on* site in 1989. The implication is that most of this volume is wastewater of relatively few large firms, managed on the premises, usually by deep-well injection, whereas relatively many small firms generate small volumes of other hazardous waste that is sent to disposal facilities.

[24]For a review of the literature on the ultimate distribution of tax burdens, see Kotlikoff and Summers (1987).

are produced by every other industry, the cost of producing each output depends on the gross-of-tax cost of buying all of its inputs. The first sub-section describes the model in general terms, while specific assumptions and equations can be found in the Appendix. The last sub-section calculates price changes attributable to existing environmental taxes.

6.1 The Input-Output Model

Virtually all of these environmental taxes apply to the purchase of an intermediate input such as chemical feedstocks or crude petroleum. Even the tax on gasoline applies to purchases of gasoline by firms that produce other goods. Superfund also imposes the corporate environmental tax (CET) on a measure of corporate income, which is part of value added. All of these taxes raise the cost of production. In any particular industry, all firms are assumed to face the same increase in cost. As these firms raise their own output price, their customers may cut back on purchases. Some of these firms may suffer losses in the short run, and eventually must cut production or exit the industry. After the dust settles, remaining firms can sell the reduced output at a higher price that just covers the new higher cost of production. Under competitive conditions, with constant returns to scale, the output price rises by exactly the increase in cost.[25] The remaining empirical issue is to determine the extent to which each price rises, that is, each industry's use of taxed inputs and of goods produced using taxed inputs.

The U.S. Commerce Department provides exactly such a matrix, for 479 different industries.[26] A column of this matrix shows, for a particular industry, the amount of each of the 479 outputs that is used as an input. For present purposes, however, fewer categories will suffice. Table 2 shows how the 479 detailed industries are aggregated into 41 categories for this study. The number and name of each industry appear in column 1, and the Standard Industrial

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[25]The equilibrium price is also likely to rise in the case of imperfect competition, but perhaps not exactly by the amount of the tax (Katz and Rosen, 1985). A monopolist would raise price by less than the tax.

[26]U.S. Commerce Department (1994, p. 73). The most recent complete input-output data are for 1987, but these amounts are scaled to 1990 for each industry using the ratio of GDP in 1990 to GDP in 1987, available in Yuskavage (1993).

Classification (SIC) appears in column 2. The aggregation basically represents the 2-digit SIC level, with some adjustments. Two-digit levels for most manufacturing industries are retained (SIC 20 through 39), but wood preserving is separated from other lumber and wood products (because wood preserving is involved in a number of contaminated sites), and petroleum refining is separated from other petroleum related products. Chemicals are divided into three categories that are taxed at different rates (taxed organic chemicals, taxed inorganic chemicals, and untaxed chemicals). Then non-manufacturing industries are collapsed into fewer categories. Just two industries are used to represent agriculture, and just one industry is used for each of: construction, transportation, wholesale trade, retail trade, finance, and services.

The whole matrix is not shown here, but the data confirm general expectations. The output of "crude petroleum and natural gas" (#5 in Table 2) is a major input to "petroleum refining" (#20), while the output of refined petroleum is a major input to "petroleum related products" (#21) and "transportation" (#32). These petroleum products are also important inputs to "organic chemicals" (#18, sometimes called "petrochemicals"). Both organic and inorganic chemicals (#17) are inputs to the other (untaxed) chemical industry (#19), and they are also major inputs to "textile mill products" (#10) and to "wood preserving" (#13).

The third column of Table 2 shows how each environmental tax in Table 1 is converted into an effective rate of tax on one of the intermediate inputs of the model.[27] In general, each effective tax rate is calculated as the observed amount of tax divided by the tax base (which most often is the total intermediate use of that input).[28] Coal, for example, is purchased primarily by the electric utilities industry (#34 in Table 2) but also to some degree by primary metals (#25) and other industries. Final demand by consumers is virtually nil. Thus the observed tax on coal is divided by total intermediate use of coal to obtain the 2.53 percent tax rate shown in Table 2.

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[27]These effective tax rates represent the statutory incidence, that is, the tax that is collected on each of these inputs. These tax rates are used here to calculate the economic incidence, that is, the increase in the 41 equilibrium output prices.

[28]The effective tax rates in Table 2 are calculated from tax amounts for 1990, because the quantities in the input-output matrix are for 1990.

Similarly, the petroleum tax applies to all purchases of crude petroleum. Unfortunately, even the most detailed input-output data employ only one industry for "crude petroleum and natural gas" (#5), and its "output" is purchased both by refineries and by utilities. Virtually all of the crude oil is purchased by refineries (#20), however, while the natural gas is purchased by gas distribution utilities (in #34). Therefore, in the model, the tax is applied not to all intermediate use of output #5, but only to the intermediate use of #5 by #20. The effective rate of tax, for both Superfund and the Oil Spill Liability Trust Fund, is 0.69 percent. This rate matches closely the statutory tax rate ($.147/barrel) divided by the average price of oil (about $20/barrel).

Chemical feedstock taxes apply at different rates on various chemicals used by any industry. Several of the 479 industries that produce taxed inorganic chemicals are aggregated into one industry (#17), where the observed tax is divided by total intermediate use to obtain an effective tax rate of 0.31 percent. Some organic chemicals (#18) are taxed as chemical feedstocks under Superfund, and some are taxed as ozone-depleting chemicals. The total of these two taxes divided by total use of taxed organic chemicals yields the effective tax rate of 0.98 percent.

Many individual chemical products are known to be taxed at rates that approach 2 percent of their price.[29] Even with 479 industries, however, the input-output matrix does not separately identify these individual products. Some of the 479 industries produced only untaxed chemicals, and these were aggregated into industry #19, but most of the chemical industries in this list produced both taxed and untaxed chemicals. Thus the categories for inorganic chemicals (#17) and organic chemicals (#18) necessarily include some untaxed chemicals. Each industry produces one "output" in the model, so this procedure effectively averages over the taxed and untaxed goods within an industry and applies a single effective tax rate to that "output".

Other taxes do not distinguish between intermediate and final purchases, so the effective rate is calculated as the observed tax over total output. The model then applies this rate to all intermediate purchases, to calculate the effect on production costs in other industries. For example, the sum of all taxes on motor fuels is divided by total output of "refined petroleum"

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[29]See Dougherty and Gilson (1994), pp. 4-2 to 4-6.

(#20) to obtain the effective tax rate of 6.94 percent shown in Table 2. The tax on tires is divided by all output of "rubber and miscellaneous plastics products" (#22) to get the 0.31 percent rate; the tax on pistols and revolvers is divided by all "fabricated metal products" (#26, 0.03 percent); taxes on trucks and gas guzzlers are divided by total output of "motor vehicles and transportation equipment" (#29, 0.39 percent); and observed taxes on transportation of persons and property are divided by total output of "transportation" (#32, 1.26 percent).

Finally, the fourth column of Table 2 shows the effective rate of corporate environmental income tax. The CET actually applies to part of profits for each firm, namely the "modified" Alternative Minimum Taxable Income (AMTI) over $2 million. A more complicated general equilibrium model might be able to calculate the effect of this tax on the wage rate and the interest rate -- and thus the extent to which the burden is passed backward onto labor and capital.[30] Instead, this simpler model assumes fixed economy-wide rates of return to labor and capital, and therefore fixed value-added in each industry. The effective tax rate for each industry is calculated as the CET liability divided by value-added in that industry. This effective rate then represents the percentage increase in value-added that is required for each industry: labor and capital must produce enough to cover this tax as well as their returns. These higher costs are reflected in output prices, and in the cost to other industries of buying those outputs as intermediate inputs. The ultimate burden is therefore passed forward, onto consumers.

The Appendix describes equations for each of the 41 industries which say that the value of output (price times quantity) is equal to the cost of all the inputs. In long run equilibrium, no firm receives excess profits. The cost side includes the price and amount of each intermediate input, and value-added. The prices of nine intermediate inputs are increased by the tax rates in column 3 of Table 2, and value-added is increased by the tax rates in column 4. Thus the 41 equations all involve the 41 prices as well as other variables. Since these equations are linear, matrix algebra is used to solve for the 41 prices as functions of the other variables (intermediate inputs, tax rates, and value added).

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[30]See, for example, Shoven and Whalley (1984).

In other words, a simultaneous solution for all prices accounts for how each price depends on all other prices of goods that may be used as inputs. This procedure considers not only taxes on the nine taxed intermediate goods, but also the increased cost of some *other* intermediate inputs that may themselves be produced using one or more of the nine taxed inputs.

6.2 Results

The percentage price increase for each of the 41 outputs is shown in the last column of Table 2. Even with these nine separate environmental taxes, only two output prices are affected by more than one percent. The price of refined petroleum (#20) rises by 1.08 percent, primarily because of the tax on input of crude oil (#5). The price of petroleum related products (#21) rises by 2.20 percent because of the increased price of refined petroleum, plus the additional tax on refined petroleum, plus the additional tax on the input of organic chemicals (#18).

The price increase for each good in Table 2 reflects the cost of inputs, not additional tax on the output. Thus the 0.86 percent increase in the price of transportation (#32) reflects not the tax on the output of the transportation industry, but increased costs of production from taxes on purchases of refined petroleum (#20) and transportation equipment (#29). The gross-of-tax price of transportation then increases by the 0.86 percent price increase *and* the 1.26 percent tax, a factor of (1.0086)(1.0126) = 1.0213 (a gross increase of 2.13 percent).

An interesting general result in Table 2 is the extent to which *every* price rises. Every industry uses some transportation and some electricity, which are produced using taxed fuels, which are produced using taxed crude petroleum. Thus Congress is not able to target the burden of particular taxes on particular industries. Another striking result in Table 2 is the extent of increases in the prices of *untaxed* goods. The price of agricultural output rises by 0.3 percent, for example, in part because that industry uses fertilizer made from taxed organic chemicals. Textile prices rise 0.3 percent, because of the use of agricultural output, chemicals, transportation, and electricity. Primary metals prices rise 0.4 percent, because of use of coal, chemicals, electricity, and transportation. Then other goods are produced using primary metals.

These tax rates and results are shown graphically in Figure 1. The long black bars for a few industries are the tax rates, and the many short white bars for all industries are the percentage increases in price. The shifting of burdens looks like mowing the tall weeds down to grass.

Similar diffuse burdens would result from incentive-based taxes on smokestack emissions or hazardous waste, since these would be paid by industries that produce goods used by other industries. The spreading of burden is not itself a problem. It just means that legislated tax policy cannot achieve the fairness objective of placing burden on a particular industry.

7. CONCLUSION

Why have separate environmental taxes? A separate tax would be needed to use incentives to discourage an activity with a negative externality that harms the environment. A good example would be a tax on a polluting emission itself, rather than on a commodity like gasoline which is only weakly correlated with emissions. But attempts to target taxes on narrowly-defined behaviors create costs of measurement, administration, and compliance. Perhaps for these reasons, as well as for political reasons, Congress prefers to control emissions and other environmentally damaging activities directly, through command and control regulations such as emission standards on all new vehicles.

Many current taxes might be thought to have environmental effects, but none of them is a good example of an incentive-based tax. Better examples might be proposed. The current tax on gasoline is not tied to emissions of carbon monoxide or hydrocarbons, but vehicle emission taxes are now becoming feasible (Harrington, Walls, and McConnell, 1994). For another example, a tax on the carbon content of each fuel would indeed be tied directly to emissions of carbon dioxide that cause global warming. For a final example, the Clean Air Act of 1990 currently hands out sulfur dioxide permits in proportion to past emissions, but it could be converted into a revenue-raising instrument by selling the permits or by taxing those emissions.

Instead, policymakers use separate taxes to finance the cleanup of each environmental problem while collecting from the industry thought to be responsible. But these attempts to target taxes on narrow industries also create substantial costs of administration and compliance. Each separate tax has a fixed cost associated with filling out forms and ensuring compliance. Thus the compliance cost per dollar of revenue starts out high while the tax rate and revenue are low. Each tax exhibits economies of scale, as an increase in the rate can acquire additional revenue without filling out more forms. A problem, then, is that each separate environmental tax requires its own forms, imposes a very low rate, and collects very little revenue.

Finally, these separate taxes and compliance costs do not achieve the goal of targeting burdens on particular industries. Using an input-output model of the U.S. economy, this paper shows how the burden of environmental taxes is distributed among all industries. Thus the high administrative and compliance costs of having many separate environmental taxes is achieving neither targeted incentives nor targeted burdens. A tiny 0.1 percent increase in broad-based income taxes would collect the same revenue, have the same diffuse distributional effects, and create virtually none of the additional administrative and compliance costs.

APPENDIX: INPUT-OUTPUT ANALYSIS

The ultimate incidence or burdens on consumers depend on 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. Under constant returns to scale and perfect competition, all increases in costs are passed onto consumers through higher prices. The burden is not only on consumers of taxed goods such as chemicals and petroleum but also on consumers of goods produced using taxed chemicals and petroleum. These price effects can be estimated using input-output analysis as developed early in the 1950s by Wassily Leontief (see Leontief, 1986) in a model like that of Probst et al (1995).

A.2 Assumptions

Several important assumptions are necessary for the model. First, the demand for every industry's output is assumed to be large enough to accommodate plenty of firms that each achieve a scale where costs are minimized. Entry barriers do not reduce the number of firms or the extent of competition. Since any change in output can be met by changes in the number of firms, all operating at minimum cost, the industry is competitive and marginal cost is constant. No firm makes abnormal profits, in the long run, after all prices and outputs have adjusted. The reasonableness of this assumption can be checked by looking at four-firm concentration ratios, the percentage of each industry output that is produced by the largest four firms in the industry.[1] When this ratio is less than half, Scherer (1979) concludes that the industry is adequately competitive. These ratios show that perfect competition and constant costs are adequate approximations of reality.[2]

Second, input coefficients are assumed fixed, so each output must be produced using unchanged proportions of each intermediate input and value-added. When one input price rises, producers cannot switch and use more of a different input. The model thus accounts for first-

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[1]These concentration ratios can be found in U.S. Commerce Department (1980). Tax incidence with imperfect competition is analyzed by Katz and Rosen (1985).

[2]More discussion on this point is in Fullerton and Tsang (1993) and Probst et al (1995).

order effects on the price of an output that is produced using a mix of intermediate inputs, but not second-order effects on changes in the mix. Also, therefore, calculated tax revenue is only an approximation. This assumption captures the effect on output price, so producers may decrease output by decreasing *all* inputs, but it misses the possibility that producers might switch from a taxed input to an untaxed input.

Third, consider the choice of assumption about international trade. If each good were traded, and if the imported good were a perfect substitute for the domestically-produced good, then any attempted change in the price of the domestic good would induce purchasers to switch entirely to the foreign good. The price of each good in the U.S. would be completely determined by world markets, and would not be affected by any domestic tax policy. At the opposite extreme, if the economy were closed, then the domestic price of each good could be determined from information on the costs of production (as in this model). But this other extreme is too restrictive. Instead, the model is still valid under the less restrictive assumption that each foreign good is an imperfect substitute for the corresponding domestic good.[3] As long as the two goods are not identical, then an increase in the price of the domestic good may induce purchasers to substitute incompletely toward the foreign good. This possibility makes the demand for the domestic good more elastic, but in this model price is independent of the shape of the demand curve. The important point here is just that the price of the domestic good is still determined by the location of the cost curve.

Finally, some indirect effects are ignored. The model is not a general equilibrium model with multiple factors of production and consumer groups with demands for each final output. Thus it does not account for changes in wages or the rate of return. For present purposes, the simpler model provides meaningful and helpful results while avoiding excessive complications.

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[3]This assumption follows Armington (1969). A Ford car is not the same as a Volvo or a Mercedes, and consumers can substitute between them in a way that depends on their relative prices. If environmental taxes on inputs raise domestic car output prices, then some consumers may switch to foreign cars. The demand for American cars may fall, but not to zero. Imperfect substitutability is irrelevant when imports are subject to the same taxes as domestic goods.

A.2 Equations

Assume that the national economy can be aggregated into n industries and a sector of final demands which includes household and government purchases. The dollar values of transactions among sectors can be presented in a transactions matrix:

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

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 ith industry. Each row shows the intermediate and final uses of an output, and each column shows 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, the unit price convention defines the physical unit of each commodity as the amount that sells for one dollar. Since all prices are one, dollar volume in (1) can be used to derive the input coefficients. Let x_j be the sum of all demands in row j, a measure of total output. Then define a_{ij} as the "input coefficient," the input of the ith good as a fraction of total output of industry j:

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

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

These input coefficients are assumed constant. This assumption is useful and appropriate for calculating first-order effects on the cost of output from variations in the cost of different inputs, as done 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:

$$(3)\qquad \begin{matrix} x_{11}p_1 + x_{21}p_2 + \cdots + x_{n1}p_n + v_1 = x_1p_1 \\ x_{12}p_1 + x_{22}p_2 + \cdots + x_{n2}p_n + v_2 = x_2p_2 \\ \vdots \quad \vdots \quad \cdots \quad \vdots \quad \vdots \quad \vdots \\ x_{1n}p_1 + x_{2n}p_2 + \cdots + x_{nn}p_n + v_n = x_np_n \end{matrix}$$

Each of these equations is divided by total output of that industry, x_i, and then rearranged and re-expressed using the input coefficients to find:

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

Using matrix algebra, these equations can then be represented by:

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

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 I is the identity matrix. If (I-A′) is nonsingular, the price vector can be derived as:

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

With the Armington (1969) assumption, each foreign good is not a perfect substitute for the corresponding domestic good. Since prices are not already set by international trade, equation (6) can be used to calculate the impact of alternative policies on the price vector.

Tax rates on nine intermediate inputs (such as petroleum and chemical feedstocks) are shown in Table 2 above. If each intermediate input has its own tax rate (regardless of where it is used), then (3) can be expressed as:

(7)
$$\begin{aligned} x_{11}p_1(1+t_1) + x_{21}p_2(1+t_2) + \cdots + x_{n1}p_n(1+t_n) + v_1 &= x_1p_1 \\ x_{12}p_1(1+t_1) + x_{22}p_2(1+t_2) + \cdots + x_{n2}p_n(1+t_n) + v_2 &= x_2p_2 \\ \vdots \qquad\qquad \vdots \qquad \cdots \qquad\qquad \vdots \qquad \vdots \quad &\quad \vdots \\ x_{1n}p_1(1+t_1) + x_{2n}p_2(1+t_2) + \cdots + x_{nn}p_n(1+t_n) + v_n &= x_np_n \end{aligned}$$

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

(8)
$$\mathbf{P} = (\mathbf{I} - \mathbf{A}'\mathbf{T}_I)^{-1}\mathbf{V}$$

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

Finally, the environmental income tax (EIT) is added to the model. If all industries face the same rate of EIT, say t, and the Alternative Minimum Taxable Income (AMTI) of each industry is a fraction, α_i, of the value-added of the ith industry, then:

(9)
$$\mathbf{P} = (\mathbf{I} - \mathbf{A}'\mathbf{T}_I)^{-1}\mathbf{T}_C\mathbf{V}$$

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

One problem in using the 1987 benchmark input-output data is that the transactions are subdivided into a make-matrix (M_{IxC}) which shows how much each industry makes of each commodity, and a use-matrix ($U_{C\times I}$) which shows how much of each commodity is used by each industry. To derive the industry-by-industry transactions matrix ($S_{I\times I}$), divide each entry of $M_{I\times C}$ by its column sum and multiply:

$$S_{I\times I} = M_{I\times C} \times U_{C\times I} \tag{10}$$

Including another row and column for value-added and final demand generates the S matrix of equation (1). The next step is to derive a_{ij} from the units convention and equation (2).

Data for T_I and T_C are shown in Table 2. For example, petroleum tax liability for 1990 is divided by intermediate use of crude petroleum by refineries to obtain t_5 of T_I. Similarly, the ratio of tax liability for each chemical divided by total intermediate uses of that chemical provides the t_i for each chemical in T_I. Column 4 of Table 2 provides the source for T_C in 1990.

Table 1: Federal Environmental Tax Rates, Revenues, and Numbers of Taxpayers

Tax	Statutory Rate, 1992	Revenue, $ millions, 1992	Number of Taxpayers	Revenue ($000) per Taxpayer
Explicit Environmental Taxes				
Petroleum, for Oil Spill Liability	$.05/barrel	273.8	312[a]	877.6
Petroleum, for Superfund	$.097/barrel	552.9	341[a]	1621.4
Chemicals, for Superfund	$.22-4.87/ton	252.2	452	558.0
Imported Chemical Substances, for Superfund	various /ton	16.5	138	119.6
Ozone-Depleting Chemicals, for General Fund (GF)	$.0205-1.67 /pound	558.2	695	803.2
Floor stocks of Ozone-Depleting Chemicals (GF)	$.18-.30 /pound	9.9	1440	6.9
Some Implicit Environmental Taxes				
Coal, mined underground for Black Lung Disability	$1.10/ton or 4.4% of value	410.6	779	527.1
Coal, surface mined for Black Lung Disability	$.55/ton or 4.4% of value	220.0	975	225.6
Tires, for Highway Trust Fund	$.15-.50 /lb.	279.9	216	1295.8
Pistols and Revolvers, for Wildlife Restoration Account	10% of value	43.4	754	57.6
Gasoline, Highway Trust Fund (HTF)[b]	$.141 /gallon	14759.3	5696	2591.2
Diesel Fuel, for HTF[b]	$.201 /gallon	4071.9	22611	180.1
Heavy Trucks and Trailers, for HTF	12% of value	904.9	3226	280.5
Gas Guzzlers, for HTF	up to $7,700 /vehicle	144.2	98	1471.4
Transportation by air, for Airport TF[c]	10% of value	4173.5	1505	2773.1
Use tax on heavy vehicles, for HTF	up to $550 /vehicle /year	596.2	3226	184.8

Source: Davie (1993) and author's calculations.

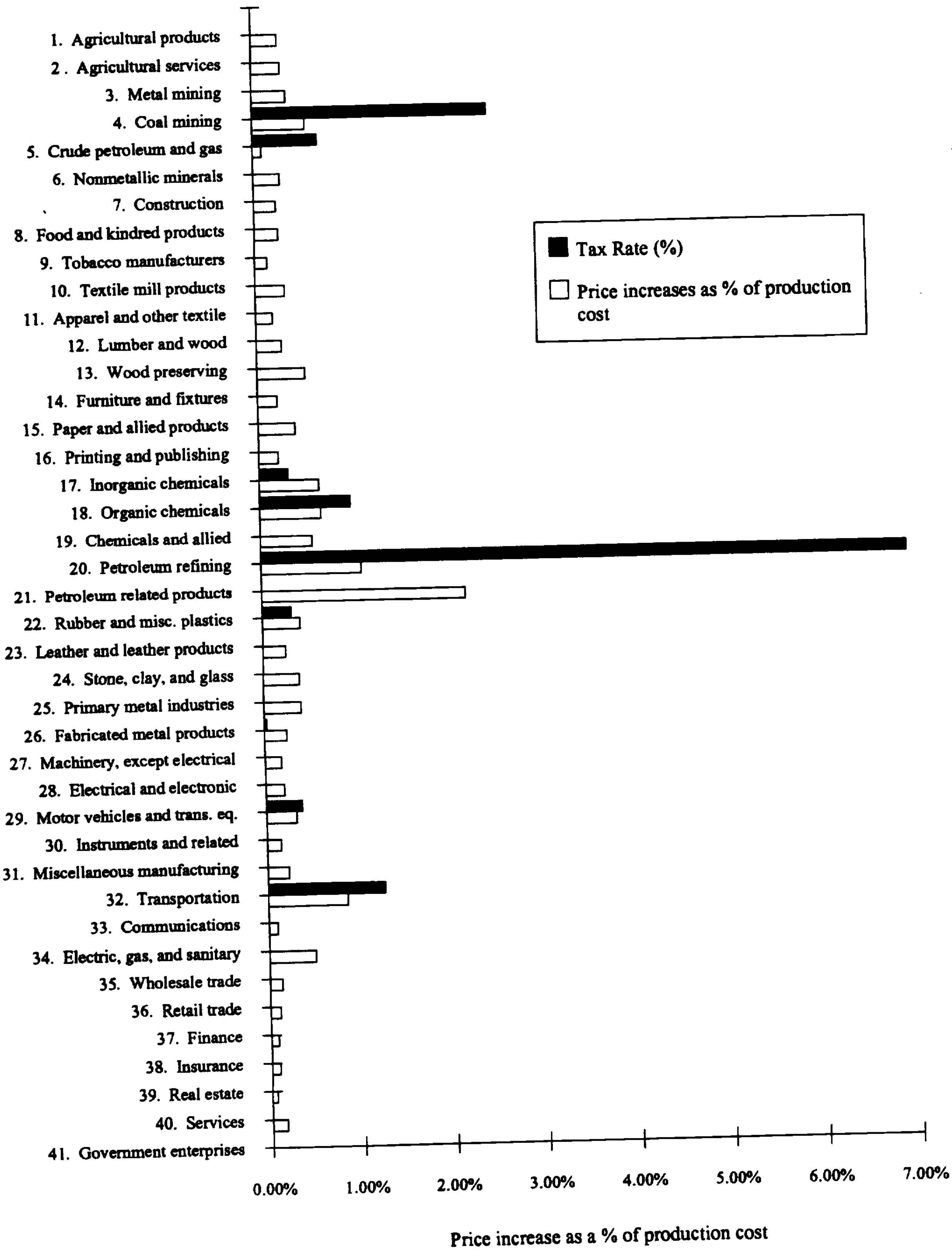
[a] This number is the sum of the numbers who pay domestic petroleum tax and imported petroleum tax. Some firms may be counted twice, but they do have to pay two separate taxes and file separate forms.
[b] The model below includes other smaller taxes on gasohol, commercial and noncommercial aviation fuels, and special motor fuels. All of these revenues are split among the Highway Trust Fund, Airport and Airway Trust Fund, Aquatic Resources Trust Fund, Leaking Underground Storage Tank (LUST) Trust Fund, and the General Fund.
[c] The model includes other smaller taxes on transportation of property by air (also for Airport and Airway Trust Fund), transporation by water (General Fund), railroads and aviation (LUST).

Table 2: Aggregation to 41 Industries, Tax Rates, and Price Increases

(1) Description	(2) Standard Industrial Classification	(3) Input Tax Rate (%)[a]	(4) EIT Rate (%)[b]	(5) Price Increase (%)
1. Agricultural products	01-02	0.00	.001	0.28
2. Agricultural services, forestry, and fishing	07-09	0.00	.002	0.31
3. Metal mining	10	0.00	.025	0.37
4. Coal mining	11-12	2.53	.006	0.57
5. Crude petroleum and natural gas	13	0.69	.009	0.09
6. Nonmetallic minerals (except fuels)	14	0.00	.008	0.29
7. Construction	15-17	0.00	.001	0.23
8. Food and kindred products	20	0.00	.015	0.25
9. Tobacco manufacturers	21	0.00	.056	0.13
10. Textile mill products	22	0.00	.006	0.31
11. Apparel and other textile products	23	0.00	.006	0.18
12. Lumber and wood products (except next entry)	24	0.00	.011	0.27
13. Wood preserving	2491	0.00	.013	0.52
14. Furniture and fixtures	25	0.00	.006	0.21
15. Paper and allied products	26	0.00	.021	0.40
16. Printing and publishing	27	0.00	.012	0.21
17. Inorganic chemicals (2812, -16, -19, -73, -74, -79)	28	0.31	.099	0.64
18. Organic chemicals (2813, -65, -69)	28	0.98	.029	0.66
19. Chemicals and allied products (except previous two)	28	0.00	.034	0.56
20. Petroleum refining	2911	6.94	.151	1.08
21. Petroleum related products (except previous entry)	29	0.00	.105	2.20
22. Rubber and miscellaneous plastics products	30	0.31	.004	0.40
23. Leather and leather products	31	0.00	.015	0.25
24. Stone, clay, and glass products	32	0.00	.014	0.39
25. Primary metal industries	33	0.00	.016	0.40
26. Fabricated metal products	34	0.03	.008	0.24
27. Machinery, except electrical	35	0.00	.018	0.18
28. Electrical and electronic equipment	36	0.00	.023	0.20
29. Motor vehicles and transportation equipment	37	0.39	.025	0.33
30. Instruments and related products	38	0.00	.009	0.15
31. Miscellaneous manufacturing	39	0.00	.016	0.23
32. Transportation	40-47	1.26	.007	0.86
33. Communications	48	0.00	.030	0.09
34. Electric, gas, and sanitary services	49	0.00	.031	0.50
35. Wholesale trade	50-51	0.00	.004	0.13
36. Retail trade	52-59	0.00	.009	0.11
37. Finance	60-62,64,67	0.00	.011	0.08
38. Insurance	63	0.00	.052	0.09
39. Real estate	65	0.00	.001	0.05
40. Services	70-89	0.00	.001	0.16
41. Government enterprises and special industries	91-97	0.00	.000	0.12

[a] Effective rate of tax on intermediate input of each good, calculated for 1990 as tax liability over the sum of all its intermediate uses.
[b] Effective rate of Corporate Environmental Income Tax (EIT) as a percent of value-added in each industry, calculated for 1990 as EIT liabilities over value-added.

Figure 1: Price Increase for Each Final Output, with Current Environmental Taxes



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