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GREEN FEES:

How a Tax Shift Can Work for the Environment and the Economy

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R.R.
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Foreword

Taxes, as the saying goes, are inevitable. But what governments tax is by no means inevitable. Today, the federal government relies largely on personal and corporate income taxes and, increasingly, payroll taxes (Social Security and Medicare). State and local governments also impose such taxes, along with sales, excise, and property taxes.

Taxes as now structured can assuredly have some perverse effects on our economy by discouraging work, savings, and investment and by distorting economic decisionmaking. Can some of our tax revenues be generated in a better way? In *Green Fees: How a Tax Shift Can Work for the Environment and the Economy,* Robert Repetto, Roger C. Dower, Robin Jenkins, and Jacqueline Geoghegan suggest that the answer is yes. They recommend the use of "green fees" such as charges on pollution, waste, and congestion. Substituting green fees for some existing taxes would not only produce a cleaner environment but would *also* reduce the economic disincentives of current taxes, thus strengthening the economy. The proposition is straightforward: we should shift some of the U.S. tax burden from activities we want to encourage—like working and investing—onto activities we want to discourage, like pollution, inefficiency, and waste. We should shift more from taxing "goods" to taxing "bads."

The same reasoning would apply if the goal is to raise additional revenues, which could be used to reduce the federal deficit. The sums that can be generated through pollution charges and other green fees are potentially quite large, and they might well be politically more acceptable—or at least less unpalatable—than conventional taxes, since they would be linked directly to environmental improvements that Americans want.

Dr. Repetto and his co-authors illustrate their point in detail by analyzing potential economic savings from three readily adoptable taxes which give citizens and corporations an incentive to curb environmentally destructive behavior: (1) pay-by-the-bag household collection charges to reduce the amount of solid waste that municipalities must dispose of; (2) rush-hour tolls to reduce congestion and air pollution on urban highways; and (3) carbon taxes to reduce carbon dioxide emissions and encourage energy-efficiency. All told, the authors estimate, these three environmental charges could yield at least $100 billion in annual revenues for federal, state, and local governments. These revenues would allow governments to reduce other, more distortionary taxes, producing net benefits to the U.S. economy. These revenues could also be used to compensate citizens who are disproportionately hit by pollution charges, to pay for needed environmental programs, or to reduce government deficits.

Environmental taxes and fees are not theoretical inventions. In various forms, they have

been enacted by individual states and localities (and by other countries) and found to be politically acceptable. Among the many possibilities are: effluent or emissions charges on a variety of toxic chemicals; deposit-return charges on batteries, tires, bottles, and other products; excise taxes on polluting products (e.g., gasoline, agricultural chemicals); and, not least, elimination of tax write-offs for environmentally damaging activities (e.g., groundwater extraction, employee parking). According to the authors, such charges work best when the activities that cause an environmental problem are well understood, widely practiced, and easily monitored; when individual cost considerations differ but each unit of activity contributes more or less proportionately to the overall problem; and when the dynamics of the problem are changing too fast for a regulatory solution to be effective.

Shifting the U.S. tax burden away from economic "goods" toward environmental "bads" would benefit the economy as a whole. Economic productivity and environmental protection are not incompatible. Indeed, the tax code could become an instrument for enhancing both at the same time.

Green Fees: How a Tax Shift Can Work for the Environment and the Economy is the latest in the World Resources Institute's continuing series of reports on options for revising tax policy and other economic incentives to curb pollution and wasteful energy use. This report's recommendations extend those of such previous WRI studies as *The Right Climate for Carbon Taxes: Creating Economic Incentives to Protect the Atmosphere; The Going Rate: What it Really Costs to Drive;* and *Driving Forces: Motor Vehicle Trends and their Implications for Global Warming, Energy Strategies, and Transportation Planning.*

We would like to thank Alida Rockefeller for her support of our research on carbon taxes and the following foundations for their support of this and other climate, energy, and pollution projects: Nathan Cummings Foundation; the German Marshall Fund of the United States; W. Alton Jones Foundation, Inc.; The Joyce Foundation; Charles Stewart Mott Foundation; The William Penn Foundation; Public Welfare Foundation, Inc.; and Rockefeller Brothers Fund. We would also like to thank Stephan Schmidheiny for his support of WRI's research on pollution taxes generally. To all of these, we express our deep appreciation.

James Gustave Speth
President
World Resources Institute

I. The Potential Gains from Shifting the Revenue Burden from Economic "Goods" to Environmental "Bads"

The U.S. economy has been foundering in recession, fiscal deficits, and loss of international competitiveness. Over the past decade, output per worker in the United States has grown only half as fast as in the rest of the industrialized world. Our productivity lead over our principal competitors is narrowing. The U.S. share in world manufacturing exports, meanwhile, has fallen by 20 percent of its level in 1970. Unsatisfactory economic performance has exacerbated fears about the costs of meeting challenges to the quality of life and environment. In recent months, for example, economic concerns have undermined the U.S. Government's willingness to protect endangered species and old growth forests in the Pacific Northwest, to protect the nation's wetlands from further encroachment, to implement stricter clean air standards, or to join other nations in preventing potentially irreversible changes in the global climate. In each case, the choice has been cast as one between environmental protection and jobs or income. The conflict is not limited to Washington, D.C. In the nation's cities and states, recession and revenue deficits are making it difficult for authorities to respond to deteriorating physical and social infrastructure and acute urban problems.

The resources with which to address these domestic and international problems are not at hand. Americans already feel burdened by taxes. Despite the anti-tax rhetoric of the past decade, government is taking a bigger bite, but U.S. capitalism is finding it harder and harder to deliver the rewards it so widely advertises.

The typical family is struggling to maintain its living standards. Between 1971 and 1990, median family income adjusted for inflation rose only from $33,191 to $34,213, a gain of only 3 percent. For families below the median, the gains, if any, were even smaller. Economic improvements over these years were achieved almost entirely through increased work, mostly by women, as the civilian labor force participation rate rose from 60 to 66 percent. For the employed, average hourly inflation-adjusted earnings in private employment fell from $8.53 in 1972 to $7.46 in 1991, and average weekly earnings declined from $315 to $256. Compared to 10 or even 20 years ago, the American population is working harder and making less.

At the same time, Uncle Sam is taking more out of the average person's paycheck. Between 1972 and 1990, personal income taxes and social security payroll taxes together have risen from 17.5 to 19.2 percent of personal income. Largely because of the rise in payroll taxes, most people have not seen any cut in the taxes they pay. There is a widespread and not unfounded perception that tax cuts are only for those with high-priced lawyers, accountants, and lobbyists.

Most people feel that they are not getting much for their tax dollars. Although the federal government spends $1,400,000,000,000 every

year and state and local governments spend an additional $800,000,000,000, the quality of education in the United States is comparatively poor, access to health care and its cost are problems, cities are unsafe, public infrastructure is deteriorating, environmental quality has improved little over time and, indeed, new global threats have emerged. Confidence in politicians and public administration is so low that most people are willing to shell out more money only if they are certain that it will be used effectively for purposes they support.

For these reasons, taxes have become extremely controversial. But political debate has dealt mainly with *how much* we tax, not *what* we tax. This is unfortunate, for *what* we tax is important. At present, our taxes fall mostly on just those activities that make the economy productive: work, savings, investment, and risk-taking. Naturally, such taxes discourage people from undertaking these vital activities. A better system would place more of the tax burden on activities that make the economy unproductive and that should be discouraged: resource waste, pollution, and congestion, for example. Taxes on these environmentally damaging activities would not distort economic decisions, but rather would correct existing distortions.

A. The Burden of Today's Tax System

Almost all taxes have incentive and disincentive effects. Although economists talk of taxes that don't affect behavior, "lump-sum taxes," there are almost no practical examples. A tax on any good or service raises its cost to the buyer while lowering the net after-tax receipts to the seller. A tax gives the buyer an incentive to cut back on what has become more expensive and to look around for a cheaper substitute. It induces the supplier to produce or offer less of the good or service for sale.

Most federal taxes fall on income and profits. Of total tax receipts in 1991 of $1.120 trillion, 41 percent came from the personal income tax, 9 percent from corporate income taxes, and 42 percent from payroll taxes. State and local governments rely more on sales, excise and property taxes, but 25 percent of their revenues also come from payroll taxes and personal and corporate income taxes. Personal income taxes are mostly taxes on wages and salaries, and, for better off taxpayers, to some extent taxes on incomes from investments and capital gains. Corporate income taxes, to the extent they are ultimately borne by stockholders, are also taxes on investments and capital gains.

Taxes on wage and salary incomes, by lowering take-home pay, tend to discourage some workers, who either withdraw from the labor force or work fewer hours than they otherwise would. These labor supply effects are most pronounced among those women and elderly and youthful workers whose commitment to full-time employment is not iron-clad. At the same time, of course, payroll taxes make workers more expensive to employers, and can prompt them to seek cheaper alternatives, such as automating or moving operations overseas.

Raising taxes on wage and salary incomes is an expensive way to raise government revenues because it reduces the economy's labor supply. The more responsive labor supply is to changes in after-tax wage rates, the greater the economic burden of income and payroll taxes. Taxes on income from investments have analogous economic costs. They lower the after-tax returns from investments and thereby induce people to seek tax shelters or to save less. An influx of investments into such shelters has an economic cost because capital is withdrawn from other investments that have a higher before-tax rate of return.

By reducing capital formation, a lower rate of savings has long-lasting and powerful effects on economic productivity and growth. The more sensitive the savings rate is to the after-tax return on investments, the greater the economic cost of taxes on capital. This is not simply a matter of personal decisions about

savings. As world capital markets become more highly integrated, it's ever more likely that an increase in U.S. taxes on investment income could send U.S. savings abroad or reduce foreign investment in this country.

Estimating these tax burdens is complicated. When the underlying issue is substituting environmental charges for conventional income and profits taxes, the relevant measure is the gain from marginally reducing income and profits taxes, when the revenues lost in this analysis are made up by higher environmental charges. For this reason, we can assume that the level of government spending remains constant. We can further assume that shifts of the tax burden among taxpayers in various brackets can be minimized through careful design of the package so that people's after-tax incomes will also be unchanged. Under these assumptions, the problem becomes one of estimating what is technically called the "marginal excess burden" of taxes.[1]

In this light, consider first the tax on labor and income. Many attempts have been made to measure the sensitivity of labor supply to the after-tax wage appropriately[2] for American male and female workers, using both actual labor market behavior and the results of income maintenance experiments. However, the numerical estimates still vary widely, according to the data sources, analytical models, and econometric techniques used to make the estimates. Table 1 summarizes the findings of numerous studies. (Pencavel, 1986, pp. 5–102; and Killingsworth and Heckman, 1986, pp. 103–200, Burtless, 1987)

According to these studies, a 10-percent rise in after-tax hourly earnings would induce a 1 or 1.5 percent rise in hours worked, if after-tax income were kept constant. For women, the response is greater, in the range of 3 to 6 percent, for the same percentage wage increase. Combining them, using the relative shares of men and women in total labor hours worked in the United States as weights, suggests that a ten percent rise in average hourly earnings would increase labor supply by roughly 2.5 percent, income and other things equal.

The problems in estimating the responsiveness of savings to changes in the interest rate savers can earn are considerably more complex, and researchers have produced an even wider range of estimates.[4] Most studies of the excess burden of taxes on capital income have estimated that if tax rates on capital income were raised ten percent, total savings would fall by four percent, while recognizing that the marginal tax rates on different forms of investment and savings differ substantially. (*See* Boskin, 1986; Ballard, Shoven, and Whalley 1985, pp. 128–138; Fullerton and Henderson 1989, pp. 435–442; Jorgenson and Yun, 1990; Trostel, 1991)

These estimates have been used along with measures of marginal tax rates in several studies to determine the marginal excess burdens of taxes in the United States. These burdens are the *additional* loss of private income due to reductions in work effort and investment, on top of the direct tax payment. All studies come to two general conclusions: the burdens are high, and the burdens of taxes

Table 1.[3] Supply of Labor Elasticity Estimates

	Number	Range	Median	Mean
Male	39	0 to .84	0.1	0.11
Female	111	0 to 2	0.29	0.57

on income from investments are higher than those on taxes on labor incomes.[5] Table 2 summarizes several of these studies. They suggest that the marginal excess burdens of payroll taxes are about $0.30 to $0.50 for every extra dollar of tax revenues collected thereby; that the marginal excess burdens of individual income taxes are in a somewhat higher range of $0.40 to $0.60 per dollar of additional revenues collected, and that the marginal excess burdens of taxes on income from investments are higher still, in the range of $0.60 to $1.20. Since some of these estimates were made before the tax cuts of the 1980s, which have lowered marginal tax rates on many incomes, the lower ends of these ranges are probably more applicable today.

These figures imply that government revenue needs are currently met through taxes that are extremely costly to the United States economy in terms of lost work and savings. People feel burdened by taxes because taxes are indeed burdensome. If considerable government revenues could be raised in non-distorting ways, allowing reductions in taxes on income, payroll, and profits, the real economic savings would be huge. Given the range of estimates above, substituting $100 billion of non-distorting taxes for a mix of current federal taxes yielding the same revenue might easily generate $40 to $60 billion yearly in additional real income. This potential-tax reform dividend is as large as the much-heralded peace dividend.

Government revenue needs are currently met through taxes that are extremely costly to the United States economy in terms of lost work and savings. People feel burdened by taxes because taxes are indeed burdensome.

The distorting effects of the current tax structure have another important implication. If additional revenue must be raised, either to reduce the federal government deficit or to finance additional expenditures, then raising it by imposing non-distorting charges and taxes is much less burdensome on the economy than increasing tax rates on income, profits and payrolls. Environmental charges, which reduce economic distortions, can provide funds for deficit reduction or expenditure needs at a much lower cost than other tax options.

The nation's cities and states stand to realize even greater economic gains through tax reform. Throughout the nation, most state and local governments are under severe fiscal pressure. Many have been facing budgetary crises. Since the mid-1980s, state and local government expenditures have outpaced revenues, undermining fiscal balances. The recessionary

Table 2. Marginal Excess Burden Estimates

Tax	Number	Range	Median	Mean
Social Security Payroll[a]	2	$0.31 to $0.48	$0.40	$0.40
Individual Income[b]	2	$0.40 to $0.60	$0.50	$0.50
Investment Income[c]	3	$0.58 to $1.18	$0.92	$0.88

a. Ballard (1991) and Jorgenson and Yun (1990).
b. Ballard (1991) and Jorgenson and Yun (1990).
c. Jorgenson and Yun (1990), Ballard (1991), and Trostel (1991).

period just ending exacerbated the imbalance, eroding tax bases while increasing both the demand for services and the costs of providing them. During 1991, a projected budget gap totalling $40 to $50 billion in all the states necessitated drastic actions. In 29 states, governments were forced to cut expenditures by more than $7.5 billion, while enacting tax increases totaling $10.3 billion. (National Governors' Association, 1991) In 1992, thirty-five states cut budgeted expenditures by a total of $5.7 billion while raising $15 billion in new taxes. (National Governors' Association, 1992) Further tax measures of this sort are expected for 1993.

Most state governments have little flexibility in dealing with these fiscal pressures. Laws or constitutional provisions require balanced budgets, even during recessions. Since states already rely heavily on sales taxes, opportunities to raise them further to offset declines in consumer spending are limited. During fiscal year 1991, over 40 percent of state revenue increases came from personal and corporate income taxes. (Belsie, 1990) Several states, including Alabama, New York, California, North Carolina, Minnesota, Missouri, Ohio, Texas, and Vermont, have already raised personal income taxes by a total exceeding $2 billion. Many states, including Alabama, Arkansas, Florida, Kentucky, North Carolina, Ohio, Rhode Island and Wisconsin, have raised corporate income taxes. (Dionne, 1991)

These tax increases are measures of desperation. Besides the considerable marginal excess burdens that they create,[6] they impose additional high costs on state economies. For the state economy, the problem is not just that a higher state personal income tax will induce some workers to work less, it is also that the higher state tax will induce some other workers to take jobs outside the boundaries of the state. Other things equal, states that impose high taxes on their citizens' personal income will discourage immigration and encourage emigration. Thus, a governor's problem is not just that a higher state tax on investment income will discourage savings. It will, but it will also discourage investment within the boundaries of the state and encourage savings to flow elsewhere.

Because labor is somewhat mobile and capital is quite mobile among states, state governments inevitably find themselves in tax competition—witness the panoply of special tax incentives they offer to attract new businesses. State and local taxes also enter the competition. Inevitably, states that raise their tax rates relative to those in force in neighboring and competing states are penalized. Of course, many households and firms are strongly tied to places and communities, and for those that do relocate, taxes are certainly not the only consideration. Nonetheless, overwhelming evidence indicates that state tax differentials influence the interstate movement of both capital and labor.

Much of this evidence has been assessed in a recent study by Timothy Bartik on state and local economic development policies. Bartik reviewed 59 empirical studies of the effects of state and local taxes on inter-metropolitan or interstate shifts in employment and business investment. These studies vary significantly in how they measure tax rates, differentials, and changes; in how they measure changes in employment or business location; and in how they control for such other relevant factors as the quality of public services and infrastructure. Accordingly, the results can be used only to establish plausible ranges for the responses to higher state taxes.

For example, five studies estimated the responsiveness of state employment to state and local income tax levels. (*See* the first panel of Table 3.) All five studies found that state and local personal income taxes have substantial and statistically significant effects on employment growth within the state, clustering around an estimate of 3.9 percent decline in employment for every ten percent rise in labor tax rates. This indicates that jobs shift substantially among localities in response to state and local taxes.[7]

Bartik also reviewed studies measuring the effects of state and local taxes on business investment and location decisions. (*See* the second panel in Table 3.) Most of these studies controlled for general regional growth differentials and for differences among states in the level of public investment. Again, the weight of evidence supports the common-sense conclusion that higher state taxes discourage business investment within the state.

For local and state economies, these studies show, increases in conventional taxes spell double trouble. They discourage work and savings as federal taxes do, and they trigger the flight of labor and capital outside the tax jurisdiction. Since labor and capital are more likely to move in response to a change in incentives than to withdraw altogether from the economy, the economic loss to the state economy from a rise in state taxes, per dollar of revenue collected, is likely to be far greater than the loss to the national economy per dollar of new federal taxes. Since economists have not attempted to measure this marginal efficiency cost of state and local taxes directly, all that can be said now with any certainty is that the efficiency losses to state and local economies from state and local taxes are substantially higher than the already high marginal excess burdens of federal taxes.

Along with serious revenue deficits, these high losses of efficiency explain the search for tax alternatives in state government offices all across the nation. For 1993, only 25 percent of the proposed tax increases come from personal and corporate income taxes. State governments seem far more willing than the federal government to impose "sin" taxes, user fees, and environmental charges. For 1993, over half of the new tax revenues are to come from increases in alcohol and tobacco taxes, gasoline taxes and motor vehicle registration fees, and other user fees. States already impose a wide variety of charges and fees related to environmental programs. Some states, notably Louisiana, South Carolina, and New Jersey, have proposed fees on hazardous waste processing facilities, fees on solid-waste facilities, and fees for emissions discharge inspections and control.

Table 3. Labor and Capital Supply Elasticities

Effect	Number	Range	Median	Mean
Taxes on Labor Supply: elasticity of employment with respect to state and local individual income taxes	5[a]	−0.66 to −0.13	−0.39	−0.38
Taxes on Capital Supply: elasticity of business location or investment with respect to state and local corporate income taxes	11[b]	−1.4 to 0.07	−0.17	−0.38

Notes:

a. Wasylenko (1988), Quan and Beck (1987), Carroll and Wasylenko (1989), Munnell (1990), Luce (1990).

b. McConell & Schwab (1990), Woodward (1990), Bartik (1989), Bauer & Cromwell (1989), Deich (1989), Papke (1986, 1987, 1989), Schmenner, Huber & Cook (1987), Bartik (1985), Garofalo & Malhotra (1983), and Hodge (1981).

The logic of environmental charges for state and local governments is especially powerful. Since the quality of life greatly influences where households and businesses locate, environmental charges that can raise revenues while improving environmental quality are more attractive than taxes that drive business and workers away.

The logic of environmental charges for state and local governments is especially powerful. Since the quality of life greatly influences where households and businesses locate, environmental charges that can raise revenues while improving environmental quality are more attractive than taxes that drive business and workers away. So far, their potential has barely been sampled.

B. The Economic (and Political) Benefits of Environmental Charges

Environmental charges are one of several incentive-based instruments of environmental policy.[8] If applied appropriately, they can harness market forces in support of environmental improvement, and promote cost-effective control of environmental problems. Unlike command-and-control regulations, they provide market signals that allow firms and households to respond in innovative and efficient ways. If there are many actors contributing to a common environmental problem—many firms burning fossil fuels and producing carbon dioxide, for example—and the cost of cutting back the offending activities differs among firms, then regulations mandating cost-effective CO_2 cutbacks would have to be complicated and costly to administer. However, a unit charge on that activity will encourage each actor to cut back to the extent that his per-unit abatement cost is less than the amount of the charge. Firms who can cut back at little cost will; those who would face much higher costs will cut back less. In the end, the unit tax will set a ceiling on costs to which all firms will adjust, and the total amount of environmental control induced by the tax will be achieved at minimum cost.

The potential gains from improved cost-effectiveness in U.S. environmental regulation are very substantial. Currently, the total cost of administering and complying with environmental regulations in the United States is around $120 billion per year, more than 2 percent of annual Gross Domestic Product. (Carlin, Scodari, and Garner, 1992, pp. 12–44) Numerous studies of specific control programs have shown that actual costs are at least twice as high as the costs that would be incurred if clean-up and control responsibilities were reallocated to achieve cost-effectiveness. (*See* Tietenberg, 1985, p. 65; South Coast Air Quality Management District, 1992)

Taxes and charges, like other environmental policy instruments, are mechanisms for dealing with the systemic failures in market incentives that arise when individual actors are not confronted with the full costs (or benefits) of their activities. For example, in communities where rubbish collection and disposal is financed through local property taxes, individual households pay the same annual amount whether they generate a lot of trash or a little. They have little incentive to adjust the amount of trash they generate to reduce waste-handling costs, even though a larger total volume of trash creates substantially higher total costs for the community.

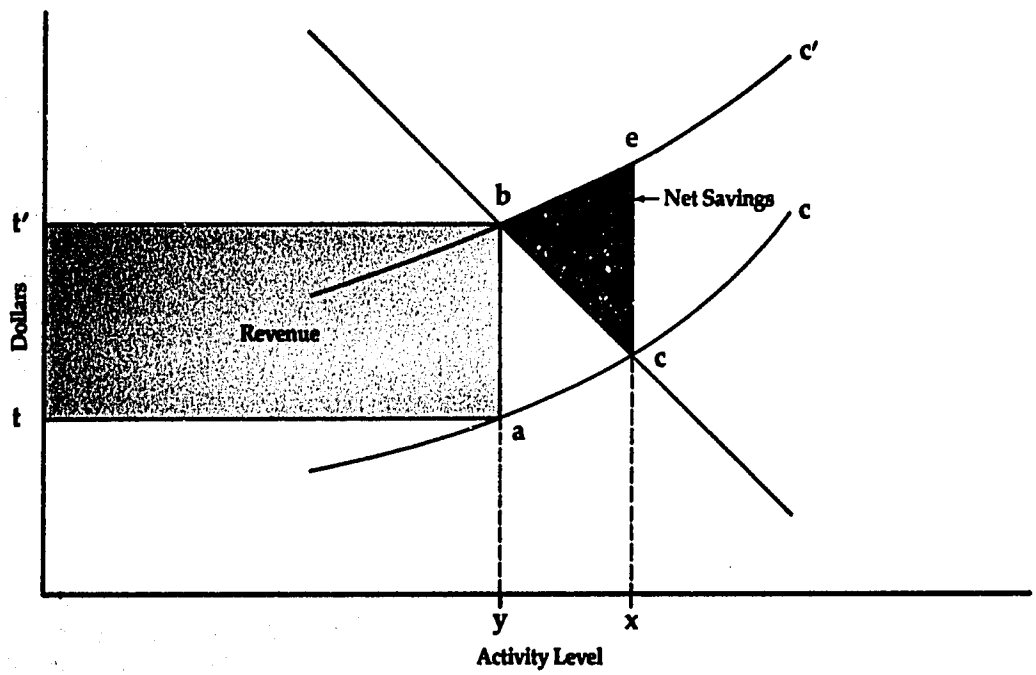
Such incentive failures are characteristic of environmental problems, because environmental resources—such as air and water—are used in common and not readily divisible into privately owned parcels. When such resources

are impaired—through the discharge of effluents, for example—the costs are diffused among all users. Unless incentive-based policies are in force, such costs cannot readily be charged to or collected from those whose activities cause the damage. Consequently, environmentally damaging activities tend to be carried to excess. That is why we suffer in the U.S. from excessive air and water pollution, noise, toxic wastes and emissions, and loss of sensitive ecosystems.

Under some conditions, an environmental charge cannot only minimize the costs of meeting any given target for control of total emissions, but also lead to an overall level of control that minimizes the sum of environmental damages and control costs. The key is setting the rate to equal the marginal damages from an additional unit of the offending activity, at just that overall level of control at which the marginal damage from an additional unit equals the marginal cost of abating it.

This situation is depicted in Figure 1. The horizontal axis represents the level of the damaging activity; the vertical axis, the costs. The line dd portrays the additional private benefits that the actor derives from successive increments of the damaging activity, and are assumed to decline. The line cc portrays the incremental private costs the actor incurs in increasing the level of activity. Taking only these private benefits and costs into account, the actor will choose a level of activity near the point x, which maximizes the private benefits net of costs. However, if the activity also imposes costs on others—by degrading an environmental resource that is used in common, for example—the total incremental costs as the

Figure 1. Revenues and Net Savings from an Environmental Charge



Source: WRI (1992)

activity expands might be portrayed as c'c'. The difference between the two cost curves represents what are called external costs, those not borne by the actor. At the level x, the activity results in incremental costs (to all parties together) that are greater than the incremental benefits. These net losses are represented by the line ce. A level of activity that maximizes overall net benefits would be at the point y, at which marginal private benefits equals marginal private and external costs. So long as activity is above this level, each unit of activity incurs net losses. The total loss is represented by the entire shaded triangle. A unit charge on the activity at a rate tt would induce the actor to reduce the level of the offending activity from x to y. The charge would bring in revenues in the amount of the rectangle ttab, the tax rate times the revenue base, which is the level of the activity after adjustment.

What is important to note in this simplified example is that, other than the costs of enforcement and administration, this charge does not create any excess burden. It has disincentive effects, but the activity that is discouraged is one that otherwise would be carried to excess and would cost society more at the margin than it is worth. In fact, by reducing the level of the environmentally damaging activity from x to y, the charge results in economic savings amounting to the area of the shaded triangle. At each level of activity between x and y, the incremental private and external costs exceed the incremental benefits, resulting in losses. Avoiding those losses results in net savings to the economy. Thus, unlike taxes that discourage economically beneficial activities, such as work and savings, environmental charges can discourage activities that, at the margin, cause economic losses. Rather than impose excess burdens, environmental charges can provide revenues and economic gains.[9]

The theoretical literature on environmental charges and other incentive-based policy instruments is enormous.[10] In the aggregate, it suggests that charges are appropriate policy instruments for dealing with certain kinds of environmental problems, though they may be inappropriate—or inferior to other approaches—in dealing with others. The circumstances under which environmental charges work particularly well, include:

- When the environmental problem is caused by the activities of numerous heterogeneous parties, so that private negotiations, permit trading, legal proceedings, or direct regulations would be difficult.

- When each party's actions contribute more or less proportionately, unit for unit, to the overall problem, so particular "hotspots" or "bad actors" are not significant.

- When the overall damages resulting from the activity are reasonably well-understood and regular—when, that is, neither catastrophic damage thresholds nor rapidly decreasing marginal damage thresholds are likely to be encountered as the level of the activity increases.

- When the various parties face significantly different abatement costs because of differences in technology, age of equipment, availability of alternatives, size, and so on.

- When the dynamics of the environmental problem are changing, so that any regulatory solution would soon be obsolete.

- When the relevant behavior of each party can be monitored accurately at reasonable cost, so that incentive-based mechanisms linked to the level of the activity are enforceable.

- When a conflicting regulatory framework based on permitted technologies or emissions levels is not already functioning, so that difficult transitional problems are not important considerations.

In circumstances other than these, other incentive-based policies can probably achieve comparable or superior gains in efficiency with

less administrative difficulty. For example, if a command-and-control regulatory system is based on permitted levels of emissions or other environmentally damaging activities, then it is typically easier to reallocate the burden of clean-up to low cost sources by making those permits salable, provided that there aren't too many regulated parties. (*See* Tietenberg, 1985)

Nonetheless, many environmental problems that would not easily yield to other incentive-based policies meet these conditions. Later chapters analyze three in some detail. The first of these deals with municipal solid waste, not because it is America's most serious environmental problem, but because it most clearly demonstrates how appropriate environmental charges can contribute to the solution. Virtually every household in America generates solid waste, and every household is different. The costs of dealing with the growing volume of waste are predictable and rising steadily. Some costs are private, such as those of waste collection. Others are external, such as the disamenities suffered by people living near landfills and incinerators. Direct regulations specifying how much of what materials each household can discharge are hardly feasible; nor can people living beside landfills sue their fellow citizens over the trash they send to the dump. Unit charges—so much per trash bag put out for collection—are an appropriate instrument. Our studies, summarized in Chapter 2, find that unit charges strongly discourage waste disposal. The resulting economic savings per dollar of revenue collected in unit charges set to reflect the full incremental costs of waste handling and disposal range from $0.05 to $0.20. The highest savings are obtainable in populous East Coast communities where solid waste costs are high because disposal options are limited.

Virtually every U.S. household owns at least one car. Road congestion is increasing in a distressingly predictable pattern. Every driver on a congested road imposes delays and additional risks of accident on all other drivers on the road, but is sensitive only to his own travel costs. Consequently, there is obviously much more rush hour traffic than is efficient. It is hard to imagine a market among commuters in rights to get on the Beltway at 8:15 am. Here again, charges, in the form of congestion tolls, are the appropriate instrument. The studies reported in Chapter 3 indicate that if appropriate congestion tolls were used on all urban arteries and collector roads, peak congestion could be reduced by 11 to 22 percent, and the net economic savings would be approximately $0.10 per dollar of revenue collected. The higher figures for congestion reduction reflect toll rates set high enough to reflect the full incremental costs of driving in heavy traffic, including the increased risks of accidents and resulting traffic tie-ups.

Everyone who burns fossil fuel or uses electricity generated with fossil fuels contributes carbon dioxide to the growing concentration in the atmosphere. In the United States, that includes everybody. All carbon dioxide emissions contribute more or less equally to the atmospheric build-up, which threatens long-lasting changes in global climate. Since the amount of carbon dioxide emitted per unit of each fossil fuel burned is known with reasonable accuracy, and since there is now no economically feasible way to prevent carbon dioxide emissions when fuels are burned, the best way to regulate emissions is to impose a tax on the carbon content of each fuel. It is not yet possible to quantify accurately the potential economic damages from climate change, so the net economic savings from an appropriate carbon tax cannot be estimated. However, studies have shown that the potential damages are substantial, perhaps as much as 1 to 2 percent of GDP. (Cline, 1992, Ch. 4) Moreover, the energy savings a carbon tax would induce would reduce U.S. emissions of other pollutants from fossil fuels. It would also help considerably in inducing other nations to institute policies to reduce carbon emissions. Therefore, though finding the appropriate rate is a challenge, some tax on carbon fuels would yield net economic savings along with revenues that could be used to reduce other distorting taxes.

The total possible gain from shifting to environmental charges could easily be $0.45 to $0.80 per dollar of tax shifted from "goods" to "bads"—with no loss of revenues.

Switching some of the revenue burden from taxes on income, employment, and profits to environmental charges on resource waste, collection, and pollution would yield double economic benefits. Reducing tax rates on income and profits would reduce the marginal excess burden by $0.40 to $0.60 per dollar of reduced tax revenue. If those revenues were regained through environmental charges, the *additional* net economic savings would range from $0.05 to $0.20 per dollar of revenue. These additional net savings are the averted environmental damages less the incremental costs of environmental protection. Putting these parts together yields the striking conclusion that the total possible gain from shifting to environmental charges could easily be $0.45 to $0.80 per dollar of tax shifted from "goods" to "bads" with no loss of revenues.[11] The gains would come in the form of improved environmental quality, reduced needs for infrastructure, higher rates of savings and investment, increased employment, and faster productivity growth. These findings refute the argument that environmental and economic goals must conflict—that environmental quality can be obtained only at the cost of lost jobs and income. Indeed, providing a better framework of market incentives by restructuring our revenue system can simultaneously improve environmental quality and make the American economy much more competitive.

The three environmental charges analyzed in detail below could yield at least $100 billion in annual revenues for federal, state, and local governments. Congestion tolls on urban highways could generate $40 to $100 billion, carbon taxes would yield $30 to $50 billion, and solid-waste charges could raise another $5 to $10 billion. Using just these three revenue sources would allow governments to reduce marginal rates of distorting taxation substantially and produce $45 to $80 billion in annual net economic benefits. Moreover, as the final chapter of this report demonstrates, many potential environmental charges in addition to these three could be used to advantage, contributing another $40 to $50 billion in revenues for tax restructuring.

Of course, *all* the revenues from such environmental charges need not be recycled through reductions in other, more distorting taxes. Some might be used to compensate citizens who are hit disproportionately by environmental charges or to make the charges more effective. Such options include spending some of the money from congestion tolls on public transport and spending some revenues from solid-waste charges on community recycling programs.[12] Some of the additional revenues might be used to reduce the federal or states' deficits. But, the gains from cuts in marginal rates of distorting taxes, which could well be greater than $0.30 on the dollar, provide a benchmark by which to judge the returns from these other options.

If the economic tradeoffs from such tax shifts are so favorable, what about the political tradeoffs? Would such a shift in the revenue base be politically acceptable? Would it be fair? The answers undoubtedly depend on the way the issue is framed. If people are asked whether they favor higher taxes, the answer is overwhelmingly no, whatever the nature of the tax. If people are asked whether they would rather be taxed on their use of energy and on the amount of waste they generate than on their salaries and profits, the answer is very likely yes.

Americans feel that their taxes are already high enough, and most have no confidence that their tax dollars are being spent wisely on

programs they endorse. Consequently, the only charges people find acceptable are those directly linked to specific, desirable expenditures. For example, though they are highly regressive and only loosely related to current or future benefit payments, payroll contributions to the Social Security Trust Fund strike Americans as among the fairest and most acceptable of the taxes they pay. Since most Americans strongly support improvements in environmental quality, they are likely to find charges directly linked to environmental improvements more acceptable than general taxes. The "polluter pays" principle, that those who cause the environmental damage bear its cost, is widely accepted as fair and efficient.

Besides, such charges give people an attractive option for savings. By substituting environmentally benign for environmentally damaging activities, they can reduce their tax bill while acting on their convictions. At present, the only way most people can reduce their tax bill is to work less and earn less income. The American public is overwhelmingly in favor of environmental protection. If environmental charges were in place, they could instead reduce their tax bills by, for instance, saving energy, bicycling to work, or recycling.

Whether to reduce the fiscal deficit, to finance high-priority expenditures, or to allow a reduction in burdensome taxes on incomes, payrolls and profits, environmental charges are the most attractive revenue option economically, and probably politically as well.

Notes for Chapter 1

1. There is a very large literature on the excess burden of taxation. A basic reference explaining the concept and estimating the excess burden of taxes on labor income is Browning (1987, pp. 11-23). *See also* Stuart (1984, pp. 352-362). For a recent explanation of the difference among various measures of tax burden, *see* Ballard and Fullerton (1992) and the literature they cite.

2. The appropriate measure in this context is the "compensated labor supply elasticity, defined as the percentage response of hours worked to a small percentage change in after-tax hourly earnings, adjusted to eliminate the (usually negative effects) of higher incomes on hours worked. If a tax increase were not offset by other tax reductions, leaving disposable income unchanged, then the more relevant measure would be the *uncompensated* labor supply elasticity, which includes income effects.

3. Some data adjustment was done on outliers. For instance, since compensated labor supply should not be negative, negative estimates were not included. However, instead of discarding those low estimates or equally extreme estimates on the high end (over 2), they were included as 0 if they were less than 0 and 2 if greater than 2. Twenty-nine out of the 150 estimates, or 19%, were changed in this way.

4. For a recent review, *see* Joel Slemrod (ed.) (1990).

5. Taxes on goods and services, such as sales and excise taxes, also create analogous economic burdens, by creating a difference between the value of the taxed item to the purchaser and its cost of production. The same elements principally determine the marginal excess burden: the elasticity of supply of the taxed item and its marginal tax rate. The marginal excess burden of broadly based sales taxes is generally estimated to be lower than that of taxes on labor and capital. *See* Jorgenson and Yun (1990).

6. Since state income taxes are deductible under federal income tax law (but not *vice versa*), an increase in the state tax rate does not increase the overall marginal tax rate accordingly. Therefore, the marginal excess burden of a state income tax is generally lower than that of a corresponding tax at federal level.

7. An earlier literature on labor mobility is assessed by Michael Greenwood (1975, pp. 91-112).

8. Others include deposit-refund systems, non-compliance fees or fines, and marketable permits for environmentally damaging activities (such as emissions). Some analysts would extend the class of incentive-based policies to include liability laws, labelling requirements, and other measures.

9. It has been pointed out that if the revenues from environmental taxes can be used to reduce other distortionary taxes, then the environmental tax rate should be set to reflect these potential gains, as well as those reducing the environmental externality. The resulting tax rate could be either higher or lower than the rate tt depicted in Figure 1, depending on the response of tax receipts to the tax rate at the rate tt. (*See* Lee and Misiolek, 1986, pp. 333-354). As a practical matter, this insight underscores the point that under these conditions, the most appropriate rate of environmental taxes, where they are feasible, cannot be zero, since a zero tax rate brings in no revenue. (*See also* Terkla, 1984, pp 107-123).

10. A classic treatment of the subject is Baumol and Oates (1975). A work focussed more on problems of application is Anderson et al. (1977). A broader review of incentive-based policies discussing potential applications is contained in *Project 88,* (1988); and *Project 88—Round II* (1991).

11. In this study, these findings are derived from studies of specific taxes considered separately. No attempt was made to take into account all the interrelated effects on product markets, labor markets, and capital markets that such a tax shift would induce. However, a recent study using what economists call a "general equilibrium" model that does take such interactions into account reaches the same conclusion. Replacing other taxes with appropriately designed environmental taxes would lead to substantial gains in economic welfare. *See* Ballard and Medema, (1992).

12. Financing such expenditures through environmental charges is far more advantageous to the economy than financing them through higher income, payroll or profits taxes. The Ballard and Medema study cited above finds that, in order to break even, an expenditure project financed through higher labor income taxes would have to return 33 cents more for each dollar of expenditure than a project with the same benefits but financed through environmental taxes.

II. Pay-By-The-Bag Household Collection Charges to Manage Municipal Solid Waste

Landfills in many American cities are filling up with trash or closing down for environmental reasons faster than new disposal facilities can be created. The pace of new landfill construction has slowed as environmental standards and community resistance have toughened, though new landfills are much larger and better designed than the old town dump. Until the recession, the volume of waste continued to increase. As a result, landfill-disposal costs are dramatically higher than a decade ago, and controversies over interregional (and international) shipments of waste have intensified.

Between 1960 and 1988, the volume of municipal solid waste[1] more than doubled, from 88 to 180 million tons. (National Governors' Association, 1990, p. 11) This averages 4.5 pounds of trash discarded daily per person, a world record. Unless current practices change, the volume is predicted to rise another 20 percent by the century's end. Although over half of this waste volume consists of categories that are readily recyclable, such as yard waste, newspapers, corrugated cardboard, and beverage containers, only 13 percent is actually recycled, *(Table 4)* and even that percentage has created a glut on most secondary markets.

Nearly three-quarters of all municipal waste is landfilled, and the remaining unrecycled fraction is incinerated. The large majority of the 6,000-odd operating landfills in the United States would not meet current environmental and operating standards for new disposal facilities. Many contain toxic wastes. In fact, almost one fifth of Superfund sites are old solid-waste dumps. Residents who live near such facilities face polluted water, methane gas infiltrating their basements, a procession of rubbish trucks, and other environmental problems. Responding to these problems, many states have upgraded standards to conform to proposed EPA regulations requiring new landfills to provide for methane gas extraction, leachate collection, surface and groundwater monitoring; and an impermeable liner. Such requirements can dramatically increase construction and operating costs for new landfills.

Such expensive improvements not withstanding, community "NIMBY" (Not in My Backyard) opposition to new landfills has stiffened. In urban regions, finding a site and getting a permit for new landfills can now take two to seven years, at a direct cost of up to $10 million. Largely for these reasons, the number of new landfill openings fell from 381 in 1970 to only 62 in 1986. (EPA, 1988, p. II-13) A recent EPA survey found that approximately 80 percent of existing landfills will reach capacity within the next 20 years. (EPA, 1988; p. 10) Twenty-eight states report less than ten years of remaining capacity, and ten states have less than five years. (Repa and Sheets, 1992)

Solid waste management problems in the densely populated parts of the United States indicate that market incentives are not inducing

Table 4. Recycling of Selected Materials, 1986 (In millions of tons and percent)

Material	Quantity	% of gross
Paper and paperboard	14.6	22.6
Glass	1.1	8.5
Ferrous metals	0.4	3.6
Aluminum	0.6	25.0
Plastics	0.1	1.0

Source: Franklin Associates, Ltd.

the right behavioral responses. A particularly egregious market failure is the absence of financial incentives for households to discard less solid waste and to recycle more. Although it costs most households nothing to put out more trash, it can cost the community well over $100 per additional ton generated. Conversely, most households save no money by recycling or composting some of their wastes, or by segregating non-recyclable and recyclable materials, though such behavior could save the community considerable amounts. Since most households pay for their rubbish collection through property taxes—a flat annual amount completely unrelated to the volume or composition of trash they discard—the incremental cost or reward to them of varying the amount or composition of their rubbish is precisely zero.

This incentive problem can be corrected by charging households the full incremental costs of waste collection and disposal through a "pay by the bag" system, and, where necessary, adjusting tipping fees to reflect disposal costs more accurately. The pay-as-you-discard approach would give households appropriate incentives to recycle, compost, and adjust their purchasing habits to reduce the volume of waste they generate. Then, consumer demand will signal producers and retailers to reduce the amount of packaging and to increase its recyclability.

A rapidly increasing number of cities and towns have already adopted pay-by-the-bag systems, selling households distinctive trash containers or stickers or tags to attach to their own containers. Usually, these systems are adopted in communities where single-family housing predominates to complement curbside recycling and other programs designed to help households reduce their disposal needs. Results have been encouraging. Pay-by-the-bag systems have been readily accepted by communities, and most have reduced the amount of waste generated. Illegal dumping and evasion have been minimal. Many households, especially those comprising elderly couples or single individuals, have found they pay less by the bag than they had previously paid in property taxes. Through such programs, local governments have also reduced waste loads and increased revenues for financing recycling programs.

In order to estimate the potential benefits of unit pricing, the experience of 10 communities across America with pay-by-the-bag systems over periods up to nine years was analyzed statistically for the effect of pricing on the tonnage of waste sent for landfilling. Although household waste disposal charges have been investigated before, this study is the latest and most complete study of household response to waste disposal charges. It finds that households respond vigorously to price signals, especially if supported by recycling options. A typical community that raised its collection fee per 32-lb. bag from zero to $1.50—in line with incremental costs—would probably induce about an 18-percent reduction in the volume of solid waste it had to landfill. If the community introduced a curbside recycling program at the same time, its landfill volume would fall about 30 percent.

There are substantial net economic savings from a shift to pay-by-the-bag collection

services. These savings are the avoided costs of waste handling and disposal *less* the additional costs to households of reducing their waste disposal. The savings were estimated separately for two kinds of communities: those in the densely populated states where disposal costs are now high (over $50 per ton); and those in regions with moderate waste-disposal costs ($20 to $49 per ton). Sparsely populated regions where waste disposal costs remain relatively low (under $20 per ton) were not regarded as likely candidates for unit pricing.

The net savings would be substantial, even under the most conservative estimates of disposal costs. As a percentage of the revenue collected in pay-by-the-bag systems without curbside recycling, net economic gains would range from 17 percent in regions where the disposal costs are high to 6 percent where they are moderate. Projected across all regions in the U.S. where waste disposal costs are moderate to high, these savings would total more than $600 million per year on annual revenues of around $6 billion. For systems including curbside recycling, in densely populated regions, the savings from reduced landfill costs would offset most of the net costs of curbside recycling programs.

If estimates of solid-waste management costs also include the costs of disamenities suffered by households living near landfills, the appropriate charges are about 60 percent higher, and the net economic savings also increase. Indeed, net savings would range from 25 percent of revenues in regions where disposal costs are high, to 11 percent in regions where they are moderate. Again, projected across all regions with high or moderate waste disposal costs, the total net savings would be almost $1.5 billion on annual revenues from collection charges of $8.8 billion.

Clearly, environmental charges can help local communities deal with an important environmental problem. By charging households for the volume of wastes they discard instead of financing waste-management services through property taxes, communities can arrest the growth of the solid waste stream, reduce collection and disposal costs, extend the lifetimes of existing landfills, and encourage household recycling while generating the revenues and cost savings needed to pay for recycling programs.

A. Households' Response to Waste-Collection Charges

In general, the more commodities households buy and use, the more waste they are likely to create. From this it follows that wealthier and larger households will tend to generate more waste. Such households even generate more yard waste (leaves and grass clippings) because they tend to live in single-family residences with larger yards.

Households can change the amount of waste they put out for disposal by recycling and composting and by altering their consumption patterns. For this reason, household solid-waste disposal responds to economic influences. Recycling takes time, for example, so high-wage or multiple-earner households in which time is very valuable are less likely to recycle, other factors being equal. The availability of time-saving curbside recycling facilities encourages recycling, especially for richer households. Recycling can save households money if the local community operates a deposit-return system for containers or offers rewards for recycled metals and newsprint. The higher such rewards of course, the more likely households are to reduce their waste disposal. Waste-disposal charges also encourage recycling and discourage consumption of overpackaged items. For purchased items destined to be thrown away—magazines, for example—the waste-collection charge becomes part of the cost of the article.

Several studies, based on experience in communities with household charges in place, have shown that collection charges tend to reduce the volume of household waste. (*See* Efaw et

al., 1979; McFariand, 1972; Skumatz, 1990; Stevens, 1978; and Wertz, 1976) In this report, to quantify the magnitude of the reduction more accurately, an econometric investigation of the effect of household waste collection charges on the tonnage of waste landfilled in a sample of fourteen U.S. communities is used. *(See Table 5.)* Of these, ten operated pay-by-the-bag or similar volume-based fee systems that they initiated at various times between 1980 and 1989, and all have kept records of the tonnage of waste collected and landfilled. The other four communities included for comparison, financed waste management systems through property taxes or flat fees and kept sufficiently accurate data on the tonnage of waste collected and landfilled.

Table 5. U.S. City Sample

1. San Francisco, California
2. The unincorporated parts of Hillsborough County, Florida
3. St. Petersburg, Florida
4. Estherville, Iowa
5. Howard County, Maryland
6. Highbridge, New Jersey
7. Bernalillo County, New Mexico (home of Albuquerque)
8. Seattle, Washington
9. Spokane, Washington
10. Wheaton, Illinois (suburb of Chicago)
11. Dolgeville, New York
12. Frankfort, New York
13. Mohawk, New York
14. Utica, New York

In this study, the effects of charges on the volume of household waste were estimated, taking into account the interactive effects of curbside recycling.[2] Also considered as influences on the volume of solid waste were population density, average household size, age distribution, average household income, the price paid for recycled newspapers, and climate variables (which particularly affect the amount of yard waste generated). In addition, specific correction factors were estimated for each community to capture other effects on the volume of waste that are independent of the level of waste collection charges. (The estimated statistical regression equation is presented in detail in *Appendix One.*)

The results indicate that a community that replaced a property tax financing system with a $1.50-per-bag waste-collection fee (a realistic estimate of incremental handling and disposal costs on the crowded Eastern Seaboard) could expect to cut waste by 0.42 lbs. per capita per day, from an average (over the entire sample) of 2.36 lbs. This is a reduction of 18 percent. If, however, the community simultaneously introduced a free curbside recycling program, the waste volume would be reduced by 0.72 lbs—more than 30 percent.

Savings like these are not hypothetical. Enough communities now have experience with charge systems that the effect on the waste stream can be verified and potential problems can be identified and forestalled. (Harder and Knox, 1992) For example, most communities have found that illegal disposal or littering can be minimized by simple measures: locking commercial dumpsters, vigorously publicizing and enforcing disposal rules in the initial months of the program; reporting households that consistently put out no refuse; and, requiring each household to pay for at least one small disposal container since all households generate some waste.[3]

Citizen response to the program in communities where it has been tried has been favorable. A large fraction of households, more than half in some communities, find that they pay less by the bag than under a flat-fee system. (USEPA, 1990) Household charges are perceived as fairer than property taxes especially if smaller bags are sold at reduced prices for those who discard little waste. Selling bags or stickers individually (instead of in packs of 10 or 20) also helps low-income households keep disposal costs manageable. Retailers are happy to sell the bags, since it brings people regularly

into the store. Providing curbside recycling options and special collection services for bulky household items (such as furniture and major appliances) has also increased the acceptability of the pay-by-the-bag system.

Local governments have also reported favorable experience with collection charges, especially where landfill costs have been rising rapidly. Most local governments first tried collection charge systems because landfill costs were rising or landfill capacity disappearing. While the volume of waste drops, saving the community money, the charge system provides revenues to finance expanded recycling programs. (USEPA, 1990)

Rubbish haulers find that the system has both advantages and disadvantages. Finding wastes neatly packed in uniform bags reduces collection costs and injuries, but households that overstuff bags with compacted wastes are a nuisance.[4] So, ironically, are households that put out no trash since the waste hauler must still complete the route but gets less to show for it. In several communities, it has been difficult to adjust the fee schedule to cover costs since the volume of waste fell dramatically once collection charges were imposed.

B. Cost Savings Under Pay-by-the-Bag Systems

1. The Costs of Solid-Waste Collection and Disposal

The economic savings from household solid-waste collection charge systems are principally the avoided costs of waste collection and disposal when the volume of waste is reduced, less the additional costs of running the charge system and any ancillary recycling programs. In the first instance, savings accrue to local governments in the form of lower waste-management costs. Ultimately, they are passed along to citizens and taxpayers who would otherwise have to pay higher property taxes or endure the environmental costs of a larger solid-waste disposal system. Against these savings are set the additional costs to households of reducing the volume of wastes set out for disposal.

Both collection and disposal costs include market and non-market components. Market costs consist largely of payments to waste haulers and landfill operators, though in many instances such payments are an imperfect approximation of actual costs. The non-market costs are the "external" costs borne by other parties, such as households living near landfills, who may suffer from noise, odor, litter, and extra traffic. (Some of these costs may of course, be reflected in market transactions: property values may be depressed by proximity to a landfill, for example.) A schematic arrangement of these market and non-market costs is presented in Table 6.

Obviously, market collection costs depend on the characteristics of the service provided: its frequency, and the option of backyard (rather than curbside) pickup, for example. For the same level of service, operators have managed to keep collection costs steady over the past decade by adopting more mechanized technologies, such as mechanical-arm trucks that require only one worker per truck. As nearby space suitable for landfills has vanished in some areas, a trade-off has emerged between higher transportation costs to haul waste to more distant landfills and higher tipping fees at local transfer stations.[5] Recent estimates of waste-collection charges range from $35 to $65 per ton. (Stone & Ashford, 1991, p. 5)

Waste disposal costs have risen rapidly in many regions. The most important factor behind the increases have been increasingly stringent environmental restrictions on landfills and incinerators, and the shortage of available new sites due to community opposition. Rising land costs and insurance costs have also played a role. The value of urban and suburban land rose rapidly in the 1980s. The average existing landfill covers 86.5 acres (EPA, 1987b, p. G3), and, so they can take full advantage of siting permits, new ones are much larger.

Table 6. Factors Influencing the Market and Non-Market Costs of Waste Disposal Services

Collection	Disposal
Market 1. Characteristics of service such as frequency of pick-up and location of collection. 2. Recent switch to less labor-intensive collection technologies. 3. Variable fuel prices.	**Market** 1. Increase in the price of land. 2. Stricter environmental regulations. 3. Heightened community opposition to residing near a disposal site.
Costs constant	Costs increasing
Non-Market 1. Probability of injury, especially to children, caused by large trash trucks operating on small residential streets. 2. Litter escaping trash truck en route to the disposal site.	**Non-Market** 1. Health threats posed by environmental damage of landfills. Threats should be reduced by stricter environmental regulations and, indirectly, by community opposition to new landfill sites. Such opposition usually leads to policies that reduce the quantities of waste discarded. 2. Aesthetic problems caused by noises and odors associated with landfills.
Costs constant	Costs decreasing

Community opposition to new landfills has greatly lengthened the siting process. The search, the hearings, the permitting process, the negotiations, and legal challenges all extend the period, and the costs of public and community relations have escalated, sometimes prohibitively. It now takes two to seven years and some $10 million to complete the siting process in an urban or suburban area.[6]

Environmental regulations governing landfill construction, operation, and maintenance have become stricter. In October 1991, the Solid Waste Disposal Criteria (USEPA, 1991) became law, giving the EPA tighter control of landfill operation and design. States have followed suit by passing more stringent standards for landfills and incinerators. Because modern landfills are much less environmentally risky and much more expensive than the old town dump, the private, market costs of waste disposal are higher.

The non-market external costs of older landfills stem from water pollution, the escape of methane gas (sometimes into basements of nearby homes), and exposure to toxic materials. Other environmental costs include odors and noise from heavy truck traffic.

Stricter regulations have converted some external non-market costs to market costs. Higher standards for new landfills have reduced the environmental damages, but raised

the costs of constructing and operating new facilities. At this point, however, few older landfills meet these standards. Only 11.5 percent have leachate collection systems, 7 percent monitor methane gas, 36 percent monitor groundwater, and 15 percent monitor surface water. (USEPA, 1987b, Appendix G) The non-market costs of most of the nation's older landfills are thus still substantial.

Strongly related to population density, both market and non-market costs of waste disposal have risen fastest in the heavily settled Eastern Seaboard. Land values are usually higher in urbanized areas. More people suffer the environmental impacts of landfills in heavily settled areas, so community NIMBY opposition is likely to be stiffer and environmental regulations stricter. (Wiseman, 1991) If states are classified according to the range of landfill tipping fees, the highest are in the New York Metropolitan region. Tipping fees are generally moderate elsewhere along the Eastern Seaboard, along the West Coast, and in the industrial Great Lakes region. *(See Table 7.)*

Unfortunately, tipping fees are a poor approximation to even the private costs of waste disposal. In some communities, private operators may be extracting monopolistic rents from the shortage of nearby landfill capacity. Still, 85 percent of landfills are publicly owned. (EPA, 1988) Municipalities rarely charge the full incremental costs of waste collection and disposal. A survey of 102 municipal authorities found that the actual costs of collection were 30 percent higher than represented in municipal accounts, which typically omitted the labor costs of vehicle maintenance, the costs of employee benefits and other items. (Savas, 1979) Direct disposal costs in municipal landfills are also substantially understated. (Reason Foundation, 1988) For example, a realistic land rent is rarely charged to the facility. A typical facility of 86 acres, often has a current market value much higher than its historical cost to the city. Few municipalities charge themselves a rent reflecting this use of valuable land. Nonetheless, since most new large landfills are privately developed and operated, it is assumed in the following analysis that for incremental landfill capacity all operating and land costs are reflected in market tipping fees.

More importantly, the operator never allows for a depletion charge as it fills up landfill

Table 7. State Tipping Fees

Greater Than $50 per Ton	Between $20 and $49 per Ton	
Connecticut	Alaska	New Hampshire
Massachusetts	California	North Carolina
New Jersey	Delaware	Ohio
New York	Florida	Oregon
	Hawaii	Pennsylvania
	Illinois	Rhode Island
	Indiana	Vermont
	Louisiana	Virginia
	Maine	Washington
	Maryland	West Virginia
	Michigan	Wisconsin
	Minnesota	

Source: Biocycle (1992, pp. 46–55).

capacity that can only be replaced at much higher cost. (Dunbar and Berkman, 1987) A depletion charge should be calculated as the discounted present value of the additional costs per ton that will be borne when the more expensive replacement facility is required. The rationale is that each ton dumped today brings closer the day when more expensive replacement capacity will be needed. In this analysis, estimated depletion costs are considered incremental costs, because the remaining lifetime of so many of the nation's landfills is less than ten years and because the costs of new capacity is so much higher. Other omitted costs, however, are ignored.

Finally, neither municipal nor private tipping fees reflect the non-market environmental costs of waste disposal. These non-market costs—including risks of air and water pollution, noise, and other disamenities—are difficult to quantify. But a study in Massachusetts provides an estimate of $75 per ton (Stone and Ashford, 1991), and in another study of California, researchers estimated costs of $67 per ton for a lined landfill with leachate collection (Tellus Institute, 1991). While neither study used a wholly satisfactory methodology, the results indicate that the non-market costs of disposal are of the same approximate magnitude as the market costs in these states where disposal is expensive. Environmental impacts in typical landfills may be greater in densely populated communities, while, in less densely populated regions, non-market costs (as well as market costs) of landfill disposal are probably lower. In the analysis that follows, it is assumed that non-market disposal costs are equal to market disposal costs in all states.

2. *Estimates of Solid-Waste Collection and Disposal Costs*

The avoided costs of waste disposal services include the market costs of collection and transportation; market disposal costs (among them, tipping fees and excluded depletion costs); external non-market costs of collection and transportation; and external non-market disposal costs.

In this study, estimates of these cost components have been assembled for two hypothetical communities: one, on the Eastern Seaboard, has high disposal costs; the other, in the Great Lakes region, has moderate disposal costs. Using these representative communities makes it possible to project the potential savings from solid waste-collection systems to a range of conditions across the United States. *(See Table 8.)*

In the 1970s and 1980s, collection costs represented two thirds to three fourths of the total market costs of municipal solid waste management (OECD, 1981, p. 14). But the rapid rise of tipping fees has reduced the share of collection costs to 25 to 50 percent.[7] In Table 8, the midpoint of this range is used, and collection costs are estimated as 37.5 percent of the total of private collection and tipping fees. Since no estimates of the external non-market costs of rubbish collection are available, this cost element is set at zero.

Tipping fees are estimated near the top of the ranges observed in high and moderate cost regions in 1992 since the recession has temporarily weakened demand for waste-disposal services and tipping fees have fallen considerably since 1990. Calculating the appropriate depletion cost was more complicated. The first element, the increased cost of replacement facilities, was estimated from an EPA study of the impact of its proposed stricter environmental requirements for new landfills. (EPA, 1988, p. 19) According to the EPA, the median increase in the costs of complying with the new landfill regulations will be approximately $10 per ton. However, complying with stricter regulations is not the only reason for higher future costs; increasing community opposition and siting difficulties are also significant. Another study estimates that the cost of time to acquire permits, the compensation that now must be paid to the community that hosts the facility, and state government special fee

Table 8. Marginal Costs of Waste Disposal Services in High and Moderate Cost Regions ($/ton)

	High-Cost Region	Moderate-Cost Region
Market Collection Costs	45	20
Market Disposal Costs	75	45
Tipping Fee	(65)	(35)
Depletion Cost	(10)	(10)
SUBTOTAL: MARKET COSTS	120	65
Non-market Collection Costs	0	0
Non-market Disposal Costs	75	45
SUBTOTAL: NON-MARKET COSTS	75	45
TOTAL	195	110

assessments on landfills, along with regulatory compliance, will raise the cost of a typical mid-western landfill by $16 per ton. (Glebs, 1988; Table 9, p. 80) As Table 9 shows, depletion costs vary directly with the replacement cost increase and inversely with the years of remaining capacity for the existing facility.

This higher replacement cost estimate of $16 per ton provides a more complete estimate of replacement cost increases. Using this figure and assuming a 10-percent interest rate and an estimated five years of remaining capacity (which is a median figure for U.S. landfills), results in an estimated $10 per ton depletion charge.

To these market costs must be added the non-market environmental costs of waste disposal. As noted, these are an estimated $75 per ton for high-cost states and $45 per ton for moderate-cost states. The incremental costs of waste handling and disposal thus total $195 per ton in such high-cost states as New York and New Jersey and $110 per ton in such moderate-cost states as Virginia and Ohio. These figures, though much higher than the estimates of solid waste costs usually cited,

Table 9. Estimates of Depletion Costs

Increase in the Tipping Fee at the Replacement Landfill	Years Before Existing Landfill is Depleted		
	Five	Three	One
$10	$6	$7.50	$9
$16	$10	$12	$14.50

reflect more accurately the economic savings in avoided costs from measures that reduce the volume of waste discarded. They thus establish a benchmark for setting appropriate solid-waste collection charges.

C. The Revenues and Net Savings from Waste-Collection Charges

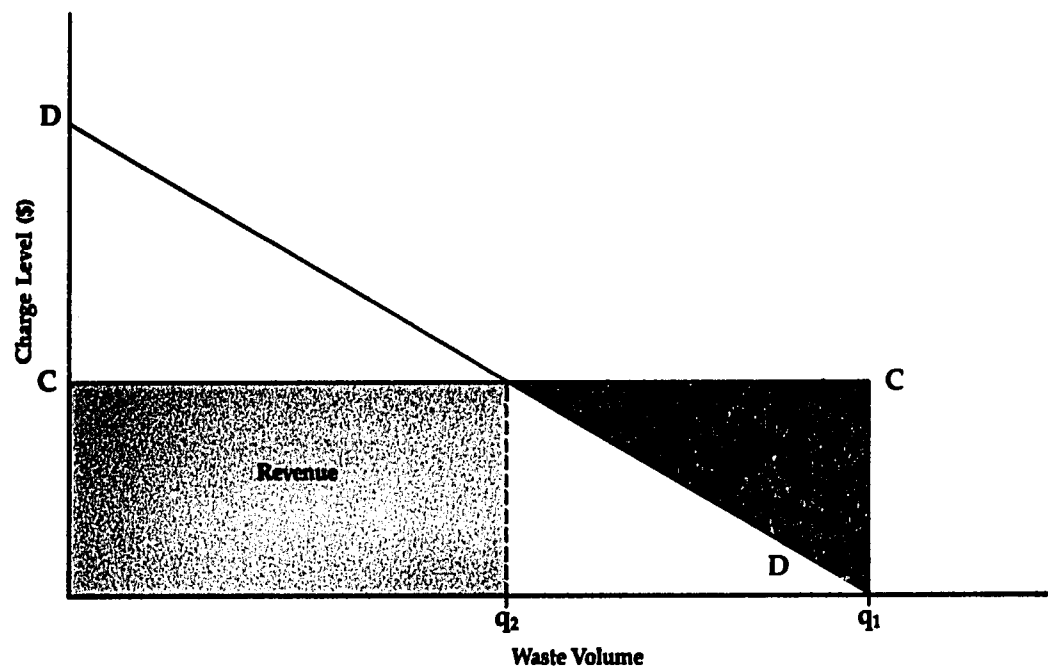
If the charges for solid-waste disposal services reflect the incremental costs discussed above, households will have an incentive to reduce the amount of waste they dispose, as long as the cost and inconvenience to them do not outweigh the charge they would otherwise have to pay. Charges set on this principle will provide households appropriate incentives to recycle and take other steps to reduce waste.[8]

Moving from a system in which households are charged nothing for each extra unit of trash set out for disposal to an appropriate pay-by-the-bag system should achieve net economic savings. Moreover, the revenues collected should be sufficient to finance the community's solid-waste collection and disposal services.

The relationship of the appropriate charge level to incremental costs, revenues, and net economic savings is portrayed graphically in Figure 2. For a hypothetical community, the relationship between the charge level and the volume of waste is depicted as the sloping demand curve DD. When services are financed through property taxes, the marginal charge is zero and the volume of waste will be q1.

The incremental costs of waste collection and disposal are represented by the line CC. It is

Figure 2. Revenue and Net Savings from a Solid Waste Unit Charge



Source: WRI (1992)

drawn horizontally on the assumption that costs per ton remain constant as the volume of wastes change. This assumption may seem surprising, since a higher volume of waste implies that landfills will fill up more quickly and depletion costs will be higher. However, offsetting this tendency is the fact that the unit costs of landfills diminish with size. On balance, considering that much of the apparent rise in costs in recent years has represented a shift from hidden non-market to monetized market costs, it seems reasonable to assume that incremental costs are constant.

If charges are set to equal incremental costs, then in Figure 2 the volume of waste is reduced to q2. The revenues generated by the charge are equal to the unit charge times the volume of waste put out for collection, or c(q2). If costs remain constant or rise, these revenues would cover the total costs of waste collection and disposal.

The net economic savings are the avoided costs of waste collection and disposal, less the costs to households of reducing the volume of waste discharged. Since households can be expected to reduce wastes to the extent that doing so is cheaper than paying for waste collection, the area underneath the demand curve DD represents the costs to households of waste reduction. The *net* savings is the area over the demand curve and underneath the incremental cost curve CC. When the charge is zero, the household has no incentive to reduce wastes, so the entire area underneath the cost curve represents a net savings. When the disposal charge equals the unit costs of disposal, then households will keep spending on waste reduction until they reach the point at which further reductions would cost as much as paying someone to take their garbage away, so no further net savings are available.

Table 10 indicates the appropriate charge level in prototypical cities in regions where garbage disposal costs are high and moderate, along with the resulting estimated revenues, waste reduction, and net economic savings. These calculations are made for charge systems without curbside recycling programs. The charges analyzed in the first panel are based only on market costs; those in the second include both the market and non-market costs of waste handling and disposal. In both cases, the potential benefits are striking.

The appropriate charges based only on market costs are $1.12 per 32-gallon bag in the high cost region and $0.60 per bag in the moderate-cost region. (Cost units have been converted from tons to 32-gallon containers assumed to hold 21 lbs. of solid waste.) Even if no curbside recycling program is in place, these charges would reduce the volume of waste discharged in the former region by 12 percent or 114 lbs per person per year and in the latter by 6.5 percent or 62 pounds per person per year. In communities of 500,000 in these regions, the charges would raise $20 million and $13 million per year, respectively. The net economic savings would be 7.5 percent of revenues collected in the region with high cost garbage disposal, and 3.5 percent of revenues in the region with low-cost disposal. Projecting these results across all states where waste management costs are moderate or high, pay-by-the-bag charges without associated curbside recycling could produce annual net savings exceeding $220 million on revenues of almost $4.7 billion.

To reflect both the market and non-market costs of waste handling and disposal, the appropriate charges would rise to $1.83 per bag in the high-cost region and $1.03 in the moderate-cost region. *(See Table 10-B.)* With charges this high, the reduction in the volume of waste, the revenues, and the net welfare gains would all increase significantly. In communities with high disposal costs, the annual volume of wastes landfilled would fall by approximately 20 percent; where costs are moderate, the drop would be 11 percent. If adopted across these regions, the annual net economic savings, including both savings in waste handling and disposal and avoided environmental damages, would total almost $650 million on annual revenues from charges of $7.25 billion.

Table 10. Revenues and Net Economic Savings Generated by Pay-by-the-Bag Charges

	High-Cost Community	Moderate-Cost Community
A. CHARGE BASED ONLY ON MARKET COSTS		
Appropriate Charge		
Per 32-Gallon Container ($)	1.12	0.60
Per Ton ($)	120	65
Reduction in Waste Landfilled (lbs/person/year)	114	62
For Community of 500,000 People		
Annual Reduction in Landfill Volume (tons)	25,500	13,915
Percentage Reduction in Landfill Volume (%)	12	6.5
Net Economic Savings ($ million/year)	1.5	0.45
Revenue from Charges ($ million/year)	20	13.1
Net Savings as a Percentage of Revenues (%)	7.5	3.5
For All High- and Moderate-Cost States		
Net Economic Savings ($ million/year)	107	114.3
Revenues from Charges ($ million/year)	1,422	3,266
B. CHARGE BASED ON MARKET AND NON-MARKET COSTS		
Appropriate Charge		
Per 32-Gallon Container ($)	1.83	1.03
Per Ton ($)	195	110
Reduction in Waste Landfilled (lbs/person/year)	187	105
For Community of 500,000 People		
Annual Reduction in Landfill Volume (tons)	41,171	23,438
Percentage Reduction in Landfill Volume (%)	19.5	10.9
Net Economic Savings ($ milion/year)	4.1	1.3
Revenue from Charges ($ million/year)	29.4	18.6
Net Savings as a Percentage of Revenues (%)	13.9	7.0
For All High- and Moderate-Cost States		
Net Economic Savings ($ million/year)	285	360
Revenues from Charges ($ million/year)	2,059	5,198

Table 11 shows the estimated results of introducing pay-by-the-bag charges along with curbside recycling. The two programs are highly complementary. Charges increase participation rates in recycling programs and the volume of material collected per household, both of which lower the unit costs of operating recycling programs. (Word, Higginbotham, and Pluenneke, 1992) The two together would greatly decrease the volume of waste to be landfilled—by up to 23 percent in the high-cost region if charges are based on market costs alone, and by 37 percent if charges are based on the combined market and non-market costs of waste handling and disposal.

In communities where disposal costs are high, net savings in market waste disposal costs are more than enough to offset the gross costs of running curbside recycling programs. (Although recycling costs vary widely among communities, an average figure of $100 per ton, ignoring any revenues from sales of materials is reasonable.) (Glenn, 1990; Powell, 1991; Snow, 1988) In a typical community of 500,000 people, appropriate charges adopted in conjunction with a curbside recycling program would generate $1.43 in net economic savings for every dollar spent on curbside recycling. Moreover, since in such estimates the costs include not only those to the municipalities but also those to households that take steps to reduce waste disposal, the actual *budgetary savings* to the municipal government from reduced handling and disposal costs, which would exclude the costs to households, are approximately twice the level of net savings—more than enough to finance recycling programs.

In communities where landfill costs are moderate, the net savings would offset almost 80 percent of gross recycling costs. Here again, though, budgetary savings would be roughly twice as great as net savings. Moreover, since the revenues from sales of recycled materials typically offset from 10 to 40 percent of the gross costs of recycling programs, the net savings from adopting pay-by-the-bag charges could offset the *net* costs of recycling programs, and the budgetary savings would offset the gross costs, even where landfill costs are moderate.

Where landfill costs are high, disposal charges would generate net economic savings of $0.17 for every dollar of revenue collected, even after the gross costs of curbside recycling programs were paid.

Basing charges on the total market and non-market costs of waste disposal would elicit much greater reduction in landfill volume, much more recycling, and much greater revenues and economic savings. In fact, where landfill costs are high, disposal charges would generate net economic savings of $0.17 for every dollar of revenue collected, even after the gross costs of curbside recycling programs were paid. The net savings after paying gross recycling costs (ignoring revenues from sales of materials) would be virtually as high as those in programs without curbside recycling. This suggests that it is more economical to introduce curbside recycling programs in conjunction with pay-by-the-bag charges in communities where landfill costs are high, even though recycling programs are expensive to operate. Adopted across all regions where waste management costs are moderate to high, pay-by-the-bag charges accompanied by curbside recycling would generate revenues of $6.3 billion per year, and net savings of $432 million after all the gross costs of recycling programs were paid.

Not all the potential benefits are reflected adequately in these estimates. Reducing the volume of waste puts off the need to find additional waste-disposal facilities or to haul municipal wastes long distances—politically divisive measures that can be counted on to generate

Table 11. Waste Reduction and Net Economic Savings from Charges Accompanied by Curbside Recycling Programs

	High-Cost Communities	Moderate-Cost Communities
A. BASED ON MARKET WASTE DISPOSAL COSTS ONLY		
Appropriate Level of Charges		
Per 32-Gallon Container ($)	1.12	0.60
Per Ton ($)	120	65
Changes in Waste Volumes		
Reduction in Landfill Volume (lbs/person/year)	190	106
Increase in Recycled Volume (lbs/person/year)	82	44
For a Community of 500,000 People		
Percent Reduction in Landfill Volume (%)	23	12
Net Saving from Landfill Reduction ($ million/year)	2.63	0.77
Increase in Recycled Volume (tons/year)	18,300	9,820
Gross Cost of Recycling ($ million/year)	1.83	0.98
Revenues from Charges ($ million/year)	17.82	10.96
For All High- and Moderate-Cost States		
Net Savings ($ million/year)	184	215
Gross Cost of Recycling ($ million/year)	128	274
Revenues ($ million/year)	1,248	3,063
B. BASED ON MARKET AND NON-MARKET WASTE DISPOSAL COSTS		
Appropriate Level of Charges		
Per 32-Gallon Container ($)	1.83	1.03
Per Ton ($)	195	110
Changes in Waste Volumes		
Reduction in Landfill Volume (lbs/person/year)	320	180
Increase in Recycled Volume (lbs/person/year)	133	75
For a Community of 500,000 People		
Percent Reduction in Landfill Volume (%)	37	21
Net Saving from Landfill Reduction ($ million/year)	6.96	2.21
Increase in Recycled Volume (tons/year)	29,688	16,741
Gross Cost of Recycling ($ million/year)	2.97	1.67
Revenues from Charges ($ million/year)	23.57	16.73
For All High- and Moderate-Cost States		
Net Savings ($ million/year)	487	618
Gross Cost of Recycling ($ million/year)	206	467
Revenues ($ million/year)	1,650	4,675

intense and acrimonious community opposition. Switching to pay-by-the-bag and curbside recycling programs offers communities new ways to avoid both these difficulties and the rapidly escalating costs of waste disposal. Moreover, such charges also remove a financial burden from property owners, who are in revolt against higher property tax rates in many parts of the country.[9]

In local government, no less than at the state and federal level, environmental charges can raise revenues while reducing environmental problems and future financing obligations. Compared to traditional revenue sources, such as property taxes, they provide superior incentives and, in the end, increase the community's economic welfare. Household solid-waste collection charges are a particularly interesting example because they have now been tried and found effective in many large and small communities around the country.

Appendices

A. A Summary of the Empirical Demand Model

The residential demand model is represented by (B.1).

$$\frac{Y^R_{it}}{POP_{it}} = a^R_1 + \frac{X^R_{it1}}{CPI_{it}} b^R_1 + \frac{X^R_{it2}}{CPI_{it}} b^R_2 + x^R_{it3} b^R_3 + \frac{X^R_{it4}}{CPI_{it}} b^R_4 \tag{5.1}$$

$$+ X^R_{it5} b^R_5 + X^R_{it6} b^R_6 + X^R_{it7} b^R_7 + X^R_{it8} b^R_8 + X^R_{it9} b^R_9 + \in^R_{it}$$

$t = 1,\ldots,Ti$, $i = 3,5,7,8,10,11,12,13,14$.

Unfortunately, several communities were unable to provide data on the quantity of residential waste alone. Instead, they kept track only of the sum of residential and commercial waste. To make use of such data we add the following two equations to our model. Equation (5.2) represents a commercial demand model. Equation (5.3) represents a demand model for the sum of commercial and residential waste disposal services.

$$\frac{Y^c_{it}}{E_{it}} = a^c_1 + \frac{X^c_{it1}}{PPI_t} b^c_1 + X^c_{it2} b^c_2 + \frac{X^c_{it3}}{PPI_t} b^c_3 + X^c_{it4} b^c_4 + X^c_{it5} b^c_5 + \in^c_{it}, \tag{5.2}$$

$t = 1,\ldots,Ti$, $i = 7$.

$$\frac{(Y^R_{it}+Y^c_{it})}{POP_{it}} = a^R_1 + \left(\frac{E_{it}}{POP_{it}}\right) a^c_1 + \frac{X^R_{it1}}{CPI_{it}} b^R_1 + \frac{X^R_{it2}}{CPI_{it}} b^R_2 + X^R_{it3} b^R_3 + \frac{X^R_{it4}}{CPI_{it}} b^R_4 + X^R_{it5} b^R_5$$

$$+ X^R_{it6} b^R_6 + X^R_{it7} b^R_7 + X^R_{it8} b^R_8 + X^R_{it9} b^R_9 + \left(\frac{E_{it}}{POP_{it}}\right) \frac{X^c_{it1}}{PPI_t} b^c_1 + \left(\frac{E_{it}}{POP_{it}}\right) X^c_{it2} b^c_2 \tag{5.3}$$

$$+ \left(\frac{E_{it}}{POP_{it}}\right) \frac{X^c_{it3}}{PPI_t} b^c_3 + \left(\frac{E_{it}}{POP_{it}}\right) X^c_{it4} b^c_4 + \left(\frac{E_{it}}{POP_{it}}\right) X^c_{it5} b^c_5 + \in^R_{it} + \left(\frac{E_{it}}{POP_{it}}\right) \in^c_{it},$$

$t = 1,\ldots,Ti$, $i = 1,2,4,6,9$.

The symbols in (5.1) through (5.3) have the following meanings.

Y_{it}^{R} = the number of pounds of residential waste disposed of per day in community i in month t;

Y_{it}^{c} = the number of pounds of commercial waste disposed of per day in community i in month t;

POP_{it} = the number of people living in community i in month t;

a_i^{R} = the fixed effect for community i related to the residential demand equation;

a_i^{c} = the fixed effect for community i related to the commercial demand equation;

E_{it} = the number of people working in community i in month t;

X_{it1}^{R} = the residential volume-based user fee per 32-gallon container in community i in month t;

X_{it2}^{R} = disposable income per household in community i in month t;

X_{it3}^{R} = the population per square mile in community i in month t;

X_{it4}^{R} = the six-month average of the market price paid by paper mills for used newspapers in community i during the six months prior to month t;

X_{it5}^{R} = the percent of the population aged 18 to 49 in community i in month t;

X_{it6}^{R} = the mean temperature in degrees fahrenheit in community i in month t;

X_{it7}^{R} = the number of inches of precipitation in community i in month t;

X_{it8}^{R} = the average number of persons per household in community i in month t;

X_{it9}^{R} = an interaction term equal to the product of the deflated residential user fee and a dummy variable for curbside recycling.

CPI_{it} = the regional consumer price index applicable to community i in month t;

X_{it1}^{c} = the weekly commercial volume-based user fee per cubic yard of dumpster capacity in community i in month t;

X_{it2}^{c} = the population per square mile in community i in month t;

X_{it3}^{c} = the six-month average of the market price paid by paper mills for used corrugated containers in community i during the six months prior to month t;

X_{it4}^{c} = the mean temperature in degrees fahrenheit in community i in month t;

X_{it5}^{c} = the number of inches of precipitation in community i in month t;

PPI_t = the national producer price index in month t;

$b_1^{R}, b_2^{R}, \ldots, b_9^{R}$ = the coefficients which correspond to the residential regressors;

$b_1^{c}, b_2^{c}, \ldots, b_9^{c}$ = the coefficients which correspond to the commercial regressors;

ϵ_{it}^{R} = the disturbance term corresponding to the residential demand model;

ϵ_{it}^{c} = the disturbance term corresponding to the commercial demand model.

Equations (5.1) through (5.3) represent the demand equations that we have estimated. The method of estimation was generalized least squares (GLS). The following table presents the coefficient vector estimated with the complete data set. The table also gives the t-statistics that correspond to each estimate.

B. Estimated Coefficients*

VARIABLE	COEFFICIENT	T-STATISTIC
DUMMY VARIABLES FOR INTERCEPTS		
Residential Dummy for San Francisco	−77.79	− 4.17
Commercial Dummy for San Francisco	105.45	3.79
Residential Dummy for Hillsborough County	− 9.41	− 1.98
Commercial Dummy for Hillsborough County	77.07	3.64
Residential Dummy for St. Petersburg	−17.51	− 3.06
Residential Dummy for Estherville	−12.04	− 3.07
Commercial Dummy for Estherville	40.89	5.93
Residential Dummy for Howard County	− 1.16	− 0.42
Combined Residential and Commercial Dummy for Highbridge	− 5.24	− 1.55
Residential Dummy for Bernalillo County	− 0.73	− 0.29
Commercial Dummy for Bernalillo County	9.56	13.10
Residential Dummy for Seattle	−28.42	− 3.95
Residential Dummy for Spokane	−45.52	− 8.03
Commercial Dummy for Spokane	103.10	10.76
Residential Dummy for Wheaton	−20.17	− 3.50
Residential Dummy for Dolgeville	− 4.20	− 1.33
Residential Dummy for Frankfort	−10.82	− 2.51
Residential Dummy for Mohawk	−15.97	− 2.98
Residential Dummy for Utica	−17.54	− 3.08
RESIDENTIAL SECTOR REGRESSORS		
User Fee for WDS (price per 30 to 32-gallon container)	− 0.28	− 2.67
Interaction Term**	− 0.20	− 2.33
Average Household Income (in thousands)	0.04	2.56
Mean Temperature	0.01	10.34
Average Precipitation	0.03	5.83
Average Household Size	− 2.40	− 2.43

APPENDIX—ESTIMATED COEFFICIENTS (continued)*

VARIABLE	COEFFICIENT	T-STATISTIC
Age Distribution of the Population	0.10	4.15
Population Density (in thousands)	4.96	4.38
Price Received for Used Newspapers (per short ton)	−0.0001	−0.13
COMMERCIAL SECTOR REGRESSORS		
User Fee for WDS (weekly price per cubic yard for two pick-ups each week)	−0.23	−2.61
Mean Temperature	0.02	4.42
Average Precipitation	−0.03	−0.97
Population Density (in thousands)	−6.28	−3.54
Price Received for Used Corrugated Containers (per short ton)	0.002	0.60
N = 636		
R^2 = 0.9305		

*The dependent variable for the residential equation is measured as pounds of refuse discarded per capita per day. The mean value of this dependent variable for the sample is 2.36. This mean is based on the average pounds per capita per day of communities for which we had residential tonnage data only.

The dependent variable for the commercial equation is measured as pounds of refuse discarded per employee per day. The mean value of this dependent variable for the sample is 7.50. This mean is based on the pounds per employee per day of the community for which we only had commercial tonnage data—Bernalillo County.

**The interaction term is equal to the product of the residential user fee and a dummy variable for curbside recycling. In particular, to calculate the interaction term we first assigned each community a value of one when a curbside recycling program was in effect and a value of zero when there was no curbside program. Then we multiplied this dummy variable by the residential user fee to get a value for the interaction term.

Notes for Chapter 2

1. Municipal solid waste includes both residential and commercial waste, the latter comprising discards from such businesses as offices, shops, and restaurants. Industrial, agricultural, and construction wastes are not categorized as municipal solid waste.

2. The original research by Robin Jenkins is reported in *The Economics of Solid Waste Reduction: The Impact of User Fees*, Edward Elgar, February, 1993. The research was extended and revised in collaboration with the World Resources Institute, and with the cooperation of Waste Management, Inc. in collecting additional field information.

3. One community that banned yard waste from collection systems but provided no other disposal alternative noted a substantial increase in illegal dumping.

4. In one community a man who bought a mechanical compactor when the unit pricing system went into effect and was putting out bags with the approximate density of kryptonite was disappointed to learn from the local authorities that his response was not in keeping with the spirit of the policy.

5. A tipping fee is the price, usually per ton or per cubic yard, that is paid by waste haulers for the privilege of dumping solid waste at a disposal site.

6. Dr. Ed Repa, Director of Technical and Research Programs at the National Solid Waste Management Association in Washington, D.C. suggested during a telephone conversation with the principal author an average siting period of 5 to 7 years. Glebs (1988, p. 5) estimates 2 to 5 years.

7. Dr. Ed Repa, Director of Technical and Research Programs, NSWMA, in personal conversation with principal investigator.

8. The charge or payment to households for the materials they set out for recycling should also reflect the incremental costs of recycling programs, of course. These are the costs of collecting and recycling the materials, net of the value of the materials in secondary markets.

9. The decline in real estate markets in the Northeast has fanned this revolt and put local communities in even tighter financial predicaments.

III. An Analysis of Tolls to Reduce Congestion on Urban Highways in the United States

Traffic congestion is a serious problem in American cities. In Los Angeles, perhaps the worst case, a ten-mile commute that took 20 minutes just two years ago now takes 30 to 35 minutes. (*Christian Science Monitor,* Nov. 28, 1990) Between 1970 and 1989, the total miles travelled by motor vehicles increased by 90 percent, the number of vehicles registered increased by over 70 percent, but urban road capacity increased by less than 4 percent. (Highway Statistics, 1989) Nearly 70 percent of rush-hour travel endures stop-and-go conditions—a 30-percent increase since 1983. Nevertheless, as of 1983, 74 percent of all drivers commuted alone in their cars, and only 15 percent carpooled. (Ferguson, 1990)

Increasing urban traffic congestion means longer delays, more accidents, wasted fuel. and more smog, acid precipitation, and greenhouse gas emissions. Congestion reduces productivity directly by lengthening the time it takes to get people, goods, and services to their destinations and indirectly by imposing added stress on all drivers. A study of 29 western cities found that in 1986 the costs of time delays and excess fuel consumption due to congestion was $17.5 billion. In Los Angeles alone, these costs total almost $6 billion a year—$3 a day per vehicle on the road. (Lomax et al., 1988)

Unless something is done, the problem will get much worse. The Federal Highway Administration (FHWA), after studying traffic patterns on urban freeways in 37 large cities, predicted that the total number of hours of delay due to congestion and accidents would increase by over 400 percent by 2005 if highway capacity remained at 1984 levels because the number of vehicle miles travelled would rise nearly 50 percent over that period. Already in 1984, 1.25 billion hours were lost in road delays; by 2005, 6.9 billion hours would be lost. This would waste an additional 7.3 billion gallons of fuel per year and increase drivers' costs by $40 billion annually. (Lindley, 1986)

Why do drivers subject themselves to this torture? There are options: travelling before or after rush hour, taking the bus, carpooling, or (in the longer run) changing where one works or lives. These options also have their costs, but in balancing them drivers are victims of a massive "market failure." The full costs of driving on crowded roads don't figure into their decisions. When drivers decide to enter a congested highway, they consider only the amount of time it will take to reach their destinations. They ignore the fact that other cars on the road will slow traffic down even more, further delaying all other drivers. For example, one additional car can cause an extra hour in delay, when summed over all drivers already on the Bay area highways during rush hour (Bay Area Economic Forum, 1990), but its driver is oblivious or indifferent to these extra costs imposed on fellow travelers. Because drivers ignore this "external" cost, thinking only of the cost of their own time, too many decide to embark on rush hour trips. The

"price" of travel is too low in that it doesn't reflect its full incremental costs.

For over 30 years, economists have advocated congestion tolls to deal with this problem. (Gómez-Ibáñez and Fauth, 1980; Goodwin and Jones, 1989; Henderson, 1974; Keeler and Small, 1977; Kraus, Mohring and Pinfold, 1976; Roth, 1970; USDOT, 1982; Vickrey, 1968, 1969; Viton, 1980; Walters, 1961) Such tolls would be based on the costs that an additional car imposes on all others during congested periods and would force drivers to make decisions that more accurately reflect their overall economic consequences. Road space during rush hour is a scarce commodity. If drivers faced all of the costs of using it, to others as well as to themselves, then road capacity would be allocated more efficiently among users.

Road space during rush hour is a scarce commodity. If drivers faced all of the costs of using it, to others as well as to themselves, then road capacity would be allocated more efficiently among users.

Congestion tolls will influence many driving decisions: the amount of travel, the timing, the route and destination, and even the choice between public and private transportation. The "right" price will induce the optimal number of trips and types of travel, where the marginal social cost of an extra trip equals the marginal social benefit it produces.

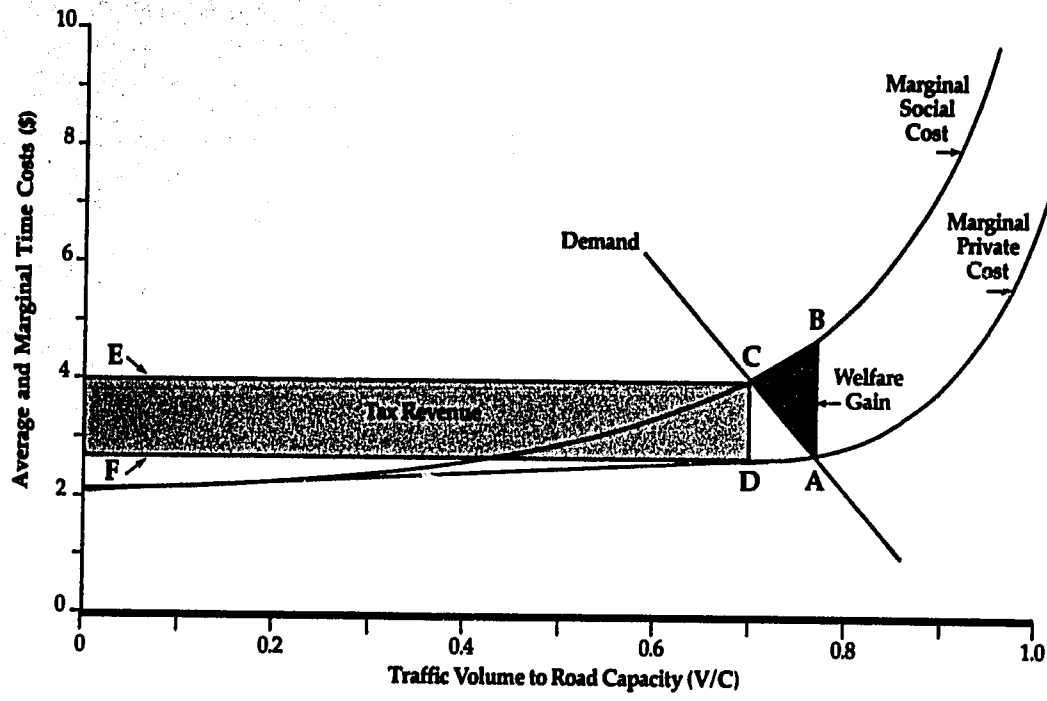
WRI has analyzed a hypothetical nationwide system of urban congestion tolls based on the full social costs of congestion. Such a system could reduce the number of vehicle miles travelled at the highest levels of congestion by as much as 22 percent and generate net economic savings of $11 billion per year. If maintained, by 1999 the reduction in vehicle miles travelled at the most congested levels could be 23 percent, with net savings exceeding $21 billion annually.

As things stand now, rush-hour travel is excessive because the social costs of driving exceed the private benefit at the margin. Figure 3 illustrates the relationship between travel costs and the level of congestion. The horizontal axis measures the ratio of traffic volume to road capacity (V/C). (Average capacity for a freeway is about 2000 passenger cars per lane per hour.) For example, a V/C ratio of one means that all available road space is taken up by vehicles. (Traffic engineers consider that traffic jams begin at a V/C ratio of 0.7.) On the vertical axis, travel costs measure the increasing time needed to travel in increasingly heavy traffic. As the V/C approaches one, and traffic slows to a standstill, time costs approach infinity.

As depicted in the private cost curve, drivers face increasing private costs as traffic increases because they must spend more time on the road. Since each additional vehicle also imposes delay costs on all other vehicles, the marginal social cost curve lies above the private cost curve. The marginal social cost equals the private cost plus the extra external cost imposed on all other drivers. External costs, which increase with the number of vehicles being held up, become increasingly severe as congestion increases, but individual drivers ignore them.

Of course, some congestion may be desirable. If a trip is so important that it would be made in the face of its full social costs, then that trip should be made, even during rush hour on a heavily used freeway. Congestion tolls will not miraculously make all congestion disappear, but will guarantee that the true costs are paid. Efficient congestion tolls, set to equal the external costs so that each driver faces the full marginal cost of the decision to drive, will lead to an efficient level of congestion: the incremental benefits to each additional

Figure 3. Congestion Costs



Source: WRI (1992)

traveler will equal the incremental costs that that driver imposes on the system. In this sense, congestion tolls promote the "right" degree of congestion.

In Figure 3, the demand curve measures the volume on the system at different levels of time cost. As those costs increase, traffic volume slackens off. At any traffic volume, the figure also indicates each user's marginal willingness-to-pay for the trip. Since the cost one is willing to assume for a trip is at most equal to the benefit derived, the demand curve also measures the benefit of an additional trip at various levels of traffic. In general, traffic will settle at the level where private benefits and costs balance (point A on Figure 3). But, at this level of traffic, full marginal costs (point B) are greater than the marginal benefits (point A). A smaller volume of traffic would be more efficient. The most efficient volume of traffic would balance private benefits and marginal social costs (point C in Figure 3). This efficient level of travel can be induced by charging a fee equal to the external costs of additional traffic at the point where marginal benefits equal marginal social costs (the distance CD). This will generate a certain amount of revenue (the rectangle CDFE in Figure 3), as all cars remaining in the system pay the toll. It will also result in an overall welfare gain to society because the total time savings as congestion is reduced outweighs the benefits given up as the volume of traffic falls (the area ABC in Figure 3).

What does this analysis mean? For one thing, it means that congestion tolls, unlike most taxes, can generate revenues and simultaneously improve economic welfare by discouraging undesirable activity. Most taxes—on income, profits, payrolls, property, or sales—have incentive effects that reduce economic

welfare by discouraging economically desirable behavior.

Moreover, congestion tolls can reduce capital outlays on highways. The authors of the recent book *Road Work* (Small, Winston and Evans, 1989) conclude that "plausible congestion tolls would reduce peak traffic volumes 10 percent to 25 percent on many congested highways. Applied to existing roads, the projected reduction could tip the balance so as to make many widening projects unnecessary; applied to new roads, it would make possible smaller and cheaper facilities in many cases." Such findings have persuaded the Secretary of Transportation, Samuel Skinner, of the merits of congestion tolls. "Peak period pricing is one important way to encourage the most effective use of existing facilities, by shifting demand that would otherwise require additional capacity to other periods or other modes where facilities are underutilized." (DOT, 1990)

In other industries in which adding capacity requires heavy capital expenditures and the level of demand fluctuates over time, using pricing incentives to shift some users from periods of peak demand to off-peak periods has proved economical. Reducing peak demand can be much cheaper than providing extra capacity that will only occasionally be used. This is what the phone companies do by giving "discounts" during evenings and weekends, which are off-peak demand periods. Many electric power utilities, instead of building more power plants, have found it more profitable to decrease peak demands by giving customers incentives to use energy more efficiently—whether by giving high-efficiency light bulbs to consumers or, say subsidizing home energy audits. Some utilities are also offering consumers lower electricity rates if they allow power to some appliances (hot water heaters, for example) to be switched off during peak demand periods. In other countries, for instance France, time-of-day electricity pricing is commonplace.

Dealing with road congestion by expanding capacity can be self-defeating as well as costly. When congestion is high, there is considerable "latent demand" for highway travel, because some drivers have been discouraged from using the roads. When capacity is increased, these extra drivers reappear to fill the new lanes, so congestion is soon as bad as it ever was. For example, when the Bay Area Rapid Transit (BART) opened in the San Francisco Bay Area, 8,750 drivers who commuted by car across the Bay Bridge switched to BART, (Sherret 1975) but 7,000 new drivers soon began commuting across the bridge so traffic remained very heavy. This illustrates the "fundamental law of traffic congestion" defined thirty years ago: "On urban commuter expressways, peak-hour congestion rises to meet maximum capacity." (Downs, 1962)

Augmenting road capacity to attack congestion has another flaw: rush-hour trips that are not work related have been increasing much faster than commuter trips. Indeed, such journeys now account for most rush hour traffic and approximately 75 percent of all weekday car trips. (Richardson and Gordon, 1989) Morning rush hour travel for non-work reasons increased by 42.1 percent between 1977 and 1983, while work related trips increased by 2.7 percent. (Gordon, Kumar and Richardson, 1988) Since such trips are probably more sensitive to cost than work trips are, congestion tolls would encourage people to reschedule many non-work-related trips now taken during the rush hours.

A. Other Costs

Time is not all that is lost in rush hour traffic. The more cars on the road, and the heavier the traffic, the more accidents occur. Road accidents already cost the nation almost $275 billion per year (Small 1991) in property damage; absences from work and related sick leave; and medical, hospital and life insurance (including administrative costs). This averages 24 cents per VMT—more than the cost of gasoline. Some of these costs are covered by insurance, but insurance premia are part of the fixed costs of car ownership and do not vary with the

Road accidents already cost the nation almost $275 billion per year in property damage; absences from work and related sick leave; and medical, hospital and life insurance. This averages 24 cents per VMT—more than the cost of gasoline.

decision to drive during rush hour, so insurance premia don't discourage overcrowding. If the increased probability of accidents were proportional to the number of cars that could possibly hit each other, then the external costs of accidents would rise as the squared power of vehicle volume, and marginal accident costs would increase at twice the rate of average costs as traffic volume increased. (Newberry, 1988) (Another study suggests that the marginal cost is one and a half times the average cost. (Vickrey, 1968, 1969)

Moreover, even drivers who don't suffer the immediate damages of an accident lose precious time whenever they get caught near one. The 1986 FHWA study estimated that in 1984 there were 766.8 million vehicle-hours of delay due to accidents and breakdowns—5 hours for each employed person. The huge external costs of accidents can be internalized with congestion tolls. To the extent that road accidents are directly related to traffic congestion, tolls can internalize their costs and reduce them.

Another consequence of congestion is extra pollution from vehicles stuck in traffic. The overall environmental health and material damages caused by vehicle pollution is conservatively estimated at 0.4 cents per VMT. (Small, 1991) This estimate covers the costs of increased human mortality and morbidity, as well as damages to materials. Although 0.4 cents per VMT is small relative to the external costs of delay and accidents, it still adds up to $8.4 billion in 1989. Furthermore, congestion and pollution levels are correlated. If traffic moved smoothly and steadily at reasonable speeds, there would be less pollution for the same number of vehicle miles travelled.

These pollution effects exclude vehicles' contribution to greenhouse warming. Nineteen pounds of carbon dioxide are released for every gallon of gasoline burned. (MacKenzie and Walsh, 1990) Other important external environmental costs from vehicle use, such as water pollution (from highway run-off) and noise pollution, are also excluded. Noise pollution from urban roads alone costs an estimated $1.8 billion in 1977 and $2.7 billion in 1985. (Fuller, et al., 1983)

For cities that cannot meet the Clean Air Act provisions, congestion tolls could help significantly. A study of an optimal toll scheme in Boston estimated that carbon monoxide concentrations would be reduced by 7 percent overall, but by up to 60 percent in the central business district. (Gómez-Ibáñez and Fauth, 1980) In the Los Angeles area, a joint study by the Environmental Defense Fund and the Regional Institute of Southern California (Cameron, 1991) found that congestion tolls would decrease carbon monoxide emissions by 12 percent, carbon dioxide by 9 percent and NO_x by 8 percent, while significantly reducing traffic congestion. This study showed the importance of reducing the number of trips as well as the total number of miles travelled. For a typical commute, about half of the pollution generated occurs during the first minute after the car is started.

According to the Reason Foundation in Southern California, the way to introduce rational road pricing is to have private toll roads. Soon this idea will be tested. Two private toll roads under construction in Orange County in Southern California and another in San Diego county may all be subject to congestion pricing. Three government-owned toll roads are under construction in Orange county, and the county government is also exploring

the idea of incorporating peak and off-peak pricing. (Poole, 1992)

According to the Bay Area Economic Forum, northern California faces the same problems that drove southern California to experiment with toll roads and two-tiered pricing systems for their use. Congestion has increased by 25% in the Bay area in just three years. (Bay Area Economic Forum, 1990) Commuters there waste almost 100 million hours per year in traffic jams. Besides the costs of lost time, damages to health, property, and plant life in the Bay area have been estimated at $300 million per year. By the year 2000, every major commuter road is predicted to be severely congested. (Bay Area Economic Forum, 1990) The Bay Area Economic Forum's report suggests that a system of efficient congestion tolls throughout the Bay area would help avert this crisis, allowing average travel speeds to increase from today's level of 15 MPH to between 45 and 50 MPH.

B. The Technology

Technologies already exist to collect congestion tolls cheaply and efficiently. The latest technologies employ battery-powered on-board devices ("tags") that can accept and store data as well as transmit it. Thus, when a vehicle enters a tollway, the device can have the time and location "written to" its memory by a stationary electronic reader in (or over) the road. When the vehicle exits the tollway, another stationary reader determines when and where the trip originated, calculates the appropriate toll, and deducts it from the account balance stored on the tag, and charges the new balance to the tag. The tag can be an electronic relay into which one inserts a credit card-like device with an imbedded microprocessor and memory. Such a card could be used in several vehicles, or could work like a debit or ATM card. It could ensure security and anonymity. Vehicles without cards—those from other regions, for example—are typically shunted to a separate manned toll lane.

In actual installations, the reliability and speed of such technologies are phenomenal. Vehicle identifications are 99.99 percent accurate, since each moving vehicle can be checked electronically at least 20 times before it gets out of reach of the toll station. (Halloran, 1992) The technologies can also be protected from theft, tampering, and other hazards. Moreover, they are cheap. In large-scale production, the cost of such tags could go below $10 each.

Several technologies and approaches have been tested in various countries. Hong Kong tested electronic number plates from 1983-1985. During this period, 2,600 government and volunteer vehicles were equipped with an "electronic number plate" (ENP). As each car crossed over an electronic "toll" site (where electronic sensors are embedded under the road), the sensor recorded the car's electronic transmission code. These toll sites ringed the central business district, so cars couldn't enter the area without registering on one of these toll sites. Each driver was sent a bill at the end of each month for the tolls charged during the period. The test proved that the technology works: there was a 99.7 percent correct identification rate of drivers, the ENPs outperformed their specifications that more than 90 percent last for at least 10 years, photographic equipment was able to detect violators, and the accounting, computer, and transmission system all functioned well. (Catling and Harbord, 1985) Had the plan gone into effect after the test period, traffic would have been reduced by an estimated 20 percent at a typical daily charge of $2.00. (Dawson and Catling, 1986)

Singapore has had an area licensing scheme in effect since 1975. Any car containing fewer than four people that enters the central business district during morning rush hour must display a sticker that costs about $2.50 a day. This is not a true congestion toll since the charge does not vary with the level of congestion, but it shows how pricing policies can reduce traffic in the most congested urban area. Right after the system was installed, traffic in the restricted areas decreased by 75 percent, mostly because of carpooling: after four

years, the comparable figure is 69 percent. As a result, travel speeds have increased by 22 percent. (Button and Pearman, 1986) Singapore, using photographic evidence to catch offenders, has a compliance rate of 98 percent, with deterrence costs of 5 percent of gross revenue. Although at first it was feared that this system would cause business to move outside the central business district, that has not happened to any significant degree. Instead, it has become easier for shoppers, workers, and goods to enter the central business district. (Watson and Holland, 1978) In 1990, the city took bids to implement a complete electronic road-pricing system, which will replace the sticker system now in use.

Electronic toll collection systems are already in place on the Santa Monica freeway, Oklahoma turnpike, Dallas North Tollway, the Crescent City Bridge and Lake Pontchartrain Causeway in Louisiana, and on other roadways in eight countries. Other such projects are under construction. Testing began recently on Interstate 190, north of Buffalo, New York, for example. England's National Economic Development Office recently predicted that the world market for traffic monitoring and managing technologies, including electronic toll systems, could expand to $45 billion in annual sales by the year 2010. Several American firms (Amtech, X-cyte, AT/Comm, and Vapor) and two British companies (Siemens Plessey, GEC Marconi) already have electronic road-pricing systems on the market. (Tomkins, *Financial Times*, Nov. 1, '91)

"Toll rings" were instituted in Bergen, Norway since 1986 and in Oslo in 1990, although these schemes were not intended to reduce congestion but to raise revenue for city road improvements. A recent study concluded that in Oslo the tolls now in effect are much lower than the external costs of congestion during peak periods, and that, as currently distributed, the tolling sites do not capture all trips with high costs related to congestion. (Larson and Ramjerdi, 1990) For these reasons, Oslo's system has done little to reduce congestion: traffic volume dropped by 5 percent when the policy was first implemented, but has since returned to the original levels. In Milan, Italy, a similar toll ring has worked better: peak-period entry fees have significantly reduced auto trips into the central city. (Arillaga & Bhatt, 1992)

In England, transport secretary Malcolm Rifkind recently recommended more research into congestion tolls. (*The Economist*, 1 June 1991) Next year, Cambridge will field test a system of congestion tolls for approximately twelve months. (Personal communication, Brian Oldridge, June 1991.) Under this scheme, a charge of 20 pence will be set for each "congestion unit," each driver must buy a "smart card" worth a set amount, and the tolls will be deducted from it as the car crosses metering points. Gas stations will sell the cards.

Interest within the European Community on the prospect of congestion tolls is high. The European Community's "DRIVE" program has a number of projects under way investigating various road-pricing technologies. Under one of these, "PAMELA" (Pricing and Monitoring Electronically of Automobiles), two-way communications equipment that will connect a moving vehicle and a roadside site for automatic payment of tolls will be designed. (Hills, 1991) The Netherlands plans to introduce congestion tolls in Amsterdam, Rotterdam, and Utrecht within the next few years. In Sweden, Stockholm is considering a system in which the "smart card" used for congestion tolls doubles as a subsidized ticket onto public transport. (Hamer, 1991; Jones, 1989)

C. Estimated Benefits of Urban Congestion Tolls Applied Nationwide

The analytical framework described in Figure 3 has been used with recent highway traffic data to estimate the impacts of congestion tolls set at appropriate levels on urban roads throughout the nation. The results show significant reductions in congestion levels, time

lost in traffic, and associated costs of accidents and pollution. In addition, congestion tolls would yield scores of billions of dollars in revenue while leaving most drivers who pay the tolls significantly better off than under the present system. Projecting these results ahead to the end of the decade demonstrates that congestion tolls could arrest the deterioration in traffic conditions on urban highways while saving nearly $50 billion in construction outlays that would otherwise be needed to expand peak capacity.

Congestion tolls could arrest the deterioration in traffic conditions on urban highways while saving nearly $50 billion in construction outlays that would otherwise be needed to expand peak capacity.

The empirical model underlying this study, based on the theoretical framework discussed above, was originally developed by Douglass Lee at the Department of Transportation for the 1982 *Final Report on the Federal Highway Cost Allocation Study*. Lee's 1982 results were recently described as follows: adopting congestion pricing throughout the United States would yield revenues of $54 billion a year (1981 dollars) which, after subtracting the direct welfare losses to road users, leaves net benefits of $5.65 billion a year—mostly in the form of annual travel-delay savings of approximately one billion vehicle-hours." (Small, Winston, and Evans, 1989)

Those results refer to the situation a decade ago. To derive more up-to-date results, the basic model was re-estimated with 1989 highway statistics (the latest available) derived from the FHWA's Highway Performance Monitoring System (HPMS). These data, derived from an annual national sample survey covering about half of all urban highways, can be extrapolated to represent the entire highway system of the United States.

Only data for urban highways in the United States were used in this study. Roads were classified into five categories: Interstates (INT), Other Freeways and Expressways (OFE), Other Principal Arteries (OPA), Minor Arteries (MA), and Collectors (COL). In 1989, the total road mileage for each classification was 11,471 (INT), 7,582 (OFE), 51,489 (OPA), 74,746 (MA), and 78,474 (COL). One hundred percent of the INT mileage was in the federal aid system, over 90 percent of the OFE, OPA, and MA roads, and about 70 percent of the collector roads. More than one trillion vehicle miles of travel were travelled on these five types of roads in 1989. *(See Table 12.)* (Some 530,015 miles of local roads outside the federal aid system were not covered in this study.

To estimate optimal congestion tolls and their impacts, it was assumed that highway capacity is fixed—a realistic assumption for the United States. Indeed, even the last decade's capacity increase of 4 percent would be hard to match in the next decade given the fiscal problems of federal and state governments. Moreover, since virtually all urban transport policy has until now been predicated on capacity expansion, with virtually no attention to demand management, it is highly likely that efforts to reduce peak road use will be the cheaper alternative.

The empirical model derives the private and social cost curves represented in Figure 3 for each category of road, and the demand curve for travel. From these, the optimal levels of congestion tolls are calculated. Then, on the assumption that these tolls are in place, the reduction in traffic at various levels of congestion can be estimated, along with levels of revenue, and reductions in time lost in traffic and other congestion costs.

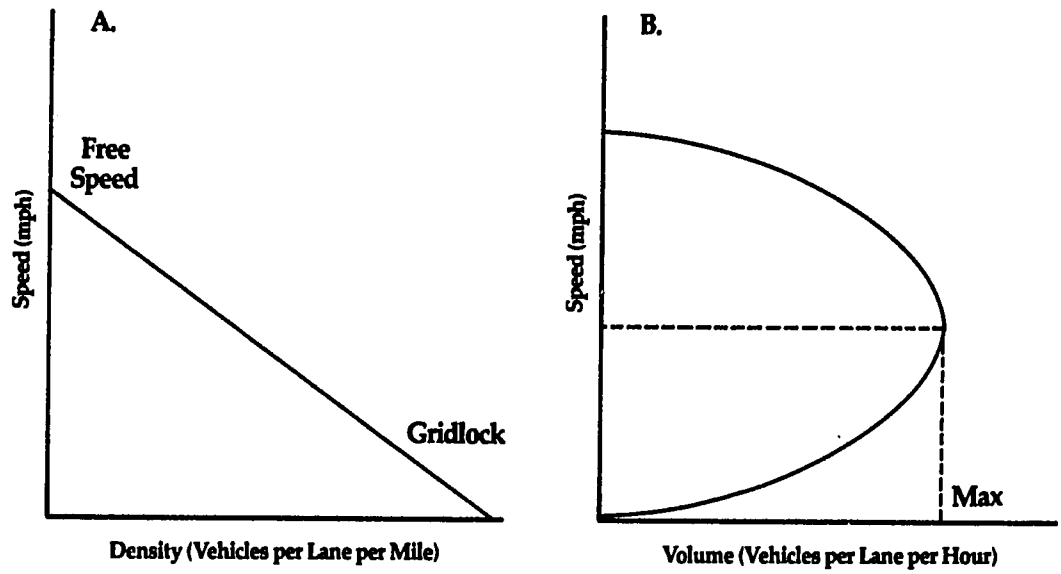
The first step is to relate the time cost of travel to the level of congestion. Since the underlying data base contains estimates of average daily traffic on the roads sampled, the

distribution of vehicle miles travelled at various V/C ratios could be calculated. The model uses as inputs the vehicle miles travelled at each level of congestion, broken into 10 unit increments. To derive average cost curves from these data, the relationship between travel speed and traffic density is fundamental since volume is the product of speed and density. (The engineering literature on the relationship between speed and density is extensive. *See,* for instance, Boardman and Lave, 1977; Fare, Grosskopf and Yoon, 1982; Inman 1978.) A reasonable approximation is that over the relevant range, speed declines linearly as traffic density increases. This implies a quadratic relationship between speed and volume. *(See Figure 4.)*

Since travel time (hours/mile) is the inverse of speed, the time cost of congestion can be estimated from this relationship once the value of travel time to the driver is known. Obviously, distinctions among drivers commuting to work, professional drivers on the job, and recreational drivers must be made. Studies suggest that non-business travel time (such as commuting to and from work) is valued at less than the hourly earnings rate, but that the gap narrows with increasing income. Various studies for the United States estimate the average value of travel time at 42 percent, 61 percent, 72 percent and 66 percent of the gross manufacturing wage rate. (Lave, 1969; Lisco, 1967; Small, 1983; Thomas, 1968) In this study, the average value of travel time is estimated conservatively at 50 percent of the gross manufacturing wage rate. (Statistical Abstracts, 1990; Small, 1991)

The result of using this analytical framework is a private marginal cost curve that rises with the level of congestion. From this, a marginal social cost curve can be derived, taking into account the delay cost that each additional car imposes symmetrically on all other cars on the road. *(See Figure 3.)* A quadratic speed-volume relationship implies that average costs and marginal costs diverge immediately, even at low traffic densities. It also implies that a marginal increase in density has the same marginal effect

Figure 4. The Relation of Speed to Traffic Density (A.) and Volume (B.)



Source: WRI (1992)

Table 12. Results of a Nationwide Congestion Toll System: 1989

	Interstates Congestion Toll	Other Freeways and Expressways Congestion Toll	Other Principal Arterial Congestion Toll
Original VMT	270,652 (million annual)	122,055 (million annual)	326,880 (million annual)
Adjusted VMT	249,647 (million annual)	113,640 (million annual)	306,056 (million annual)
Percent Reduction	7.8	6.9	6.4
Toll Range	0-9 (cents/mile)	0-11 (cents/mile)	0-12 (cents/mile)
Revenue Generated	12.7 (billion dollars annual)	5.5 (billion dollars annual)	13.6 (billion dollars annual)
Most Congested VMT	159,707 (million annual)	55,015 (million annual)	118,320 (million annual)
After Toll	143,290 (million annual)	49,055 (million annual)	105,112 (million annual)
Percent Reduction	10.3	10.8	11.2
Welfare Gains	1.4 (billion dollars annual)	0.6 (billion dollars annual)	1.2 (billion dollars annual)
	With Accident Toll	**With Accident Toll**	**With Accident Toll**
Adjusted VMT	239,950 (million annual)	109,879 (million annual)	299,986 (million annual)
Percent Reduction	11.3	10.0	8.2
Toll Range	0-16 (cents/mile)	0-17 (cents/mile)	0-19 (cents/mile)
Revenue Generated	23.0 (billion dollars annual)	9.5 (billion dollars annual)	22.7 (billion dollars annual)
Adjusted Congested VMT	133,708 (million annual)	45,349 (million annual)	99,213 (million annual)
Percent Reduction	16.3	17.6	16.1
Welfare Gains	2.7 (billion dollars annual)	1.1 (billion dollars annual)	2.1 (billion dollars annual)
	With Accident Delay Toll	**With Accident Delay Toll**	**With Accident Delay Toll**
Adjusted VMT	229,459 (million annual)	106,267 (million annual)	294,033 (million annual)
Percent Reduction	15.2	12.9	10.0
Toll Range	0-24 (cents/mile)	0-26 (cents/mile)	0-27 (cents/mile)
Revenue Generated	33.2 (billion dollars annual)	13.0 (billion dollars annual)	29.9 (billion dollars annual)
Adjusted Congested VMT	123,217 (million annual)	41,737 (million annual)	93,539 (million annual)
Percent Reduction	22.8	24.1	20.9
Welfare Gains	4.2 (billion dollars annual)	1.6 (billion dollars annual)	3.1 (billion dollars annual)

on speed, no matter what the initial level of speed.

Although this cost structure was adopted from the original Department of Transportation model, a number of theoretical and empirical adjustments were made to the demand estimates. First, all cars forced off the road by increasing time costs do not simply disappear. Some drivers shift to other roads; others reschedule their travel. A reduction in traffic on one highway segment may show up, at least in

Table 12. (continued)

	Minor Arterial Congestion Toll	Collector Congestion Toll	Total Congestion Toll
Original VMT	234,860 (million annual)	101,190 (million annual)	1,055,637 (million annual)
Adjusted VMT	222,221 (million annual)	97,588 (million annual)	989,153 (million annual)
Percent Reduction	5.4	3.6	6.3
Toll Range	0–15 (cents/mile)	0–21 (cents/mile)	0–21 (cents/mile)
Revenue Generated	9.1 (billion dollars annual)	3.0 (billion dollars annual)	44.1 (billion dollars annual)
Most Congested VMT	55,490 (million annual)	10,900 (million annual)	399,432 (million annual)
After Toll	48,185 (million annual)	9,322 (million annual)	354,964 (million annual)
Percent Reduction	13.2	14.5	11.1
Welfare Gains	0.8 (billion dollars annual)	0.2 (billion dollars annual)	4.2 (billion dollars annual)
	With Accident Toll	**With Accident Toll**	**With Accident Toll**
Adjusted VMT	219,653 (million annual)	97,240 (million annual)	966,708 (million annual)
Percent Reduction	6.5	3.9	8.4
Toll Range	0–22 (cents/mile)	0–28 (cents/mile)	0–28 (cents/mile)
Revenue Generated	14.0 (billion dollars annual)	4.2 (billion dollars annual)	73.4 (billion dollars annual)
Adjusted Congested VMT	45,696 (million annual)	9,005 (million annual)	332,971 (million annual)
Percent Reduction	17.7	17.4	16.6
Welfare Gains	1.2 (billion dollars annual)	0.3 (billion dollars annual)	7.3 (billion dollars annual)
	With Accident Delay Toll	**With Accident Delay Toll**	**With Accident Delay Toll**
Adjusted VMT	217,241 (million annual)	96,913 (million annual)	943,912 (million annual)
Percent Reduction	7.5	4.2	10.6
Toll Range	0–30 (cents/mile)	0–36 (cents/mile)	0–36 (cents/mile)
Revenue Generated	17.4 (billion dollars annual)	4.9 (billion dollars annual)	98.4 (billion dollars annual)
Adjusted Congested VMT	43,285 (million annual)	8,677 (million annual)	310,455 (million annual)
Percent Reduction	22.0	20.4	22.3
Welfare Gains	1.6 (billion dollars annual)	0.3 (billion dollars annual)	10.8 (billion dollars annual)

part, as increased traffic at another time or place. These substitutions are taken into account by assuming that drivers choose among different routes and travel times to minimize travel costs and the costs of shifting the trip to a less desirable time. If congestion costs rise on the most preferred route and time, the demand for travel on that route declines, but demand increases on substitute routes and times.

The more responsive drivers are to changes in the price of travelling, the more effective

congestion tolls will be. Drivers' responsiveness is summarized by a curve representing the amount of travel at various travel costs. Since drivers balance the marginal costs and benefits of travelling, in the absence of a congestion toll, traffic will settle where the demand curve (marginal benefit curve) meets the private marginal cost curve, while the social optimum will occur where the marginal benefit curve crosses the social marginal cost curve. The less responsive drivers are to travel costs, the larger the tax necessary to induce a given reduction in traffic, so the measure of drivers' sensitivity to cost is very important.

Unfortunately, there are no direct empirical estimates of this sensitivity since there has been no peak pricing of highway use in the United States. Indirect estimates have yielded a range of values. (Gómez-Ibáñez & Fauth, 1980) In this study, DOT's assumptions were followed: a ten percent increase in the cost of driving at a specific time and place would reduce the volume of traffic at that point by 2.7 percent. (Small, 1991) Given the private and social cost curves, this estimate can be used to estimate the optimal congestion tolls and other quantities in the model.

However, knowing this value is not enough to complete the analysis. A measure of intertemporal substitution of demand is also needed because when the cost of travel at peak periods rises, some people will decide to travel at other times. Just how much travel will be shifted to off-peak times has been the subject of a huge literature. An overall schedule delay cost was estimated by Small (1991) based on previous work (Arnott, De Palma and Lindsey, 1990). Assuming that the cost per minute of displacement from the driver's ideal departure time is constant as the schedule delay increases, and assuming further that drivers plan their travel to minimize *total* travel costs, the analysis estimated the time-shifting to off-peak hours that congestion tolls would induce. In general, as Small suggests, congestion tolls would stimulate substantial adjustment in departure times to avoid congestion and higher toll costs.

Second, when a city driver chooses a route to a given destination, the major consideration is how long it will take to get there. A longer route may be preferable to a shorter one if congestion is lower and travel speeds are higher on the longer route. Drivers will make this trade-off as long as any gains can be made from switching roads. Therefore, congestion tends to even out on all alternative routes, as all rush hour commuters know. If this were not the case, then time could consistently be saved by choosing a different route. In this study, it was assumed that the observed distribution of vehicle miles travelled on alternative routes represents an equilibrium resulting from drivers' attempts to minimize costs. When congestion tolls are imposed, the costs then consist of time costs *plus* tax costs, changing the relative prices of different routes. Paying both induces some drivers to switch to other roads. In order to capture this substitution effect, vehicle miles travelled over alternative routes were adjusted so that marginal private costs (time plus toll costs) were again equalized after the imposition of tolls. Like the adjustment made to reflect drivers' rescheduling of trips, this reallocation of traffic across road segments further cuts peak congestion traffic.

With a tax, travel under the most congested conditions would drop by 11 percent. The savings in time otherwise lost in traffic delays creates a $4.2 billion annual economic gain, net of the value of the trips foregone.

This basic model was estimated with 1989 data to derive optimal congestion tolls reflecting the costs of traffic delays. As the first row of Table 12 shows, on major urban highways, appropriate rush hour congestion tolls would range from $0.00 to $0.21 per mile, less than two dollars for a typical urban trip of ten miles

or less. Total traffic volume would fall by about 6 percent, and travel under the most congested conditions would drop by 11 percent. The savings in time otherwise lost in traffic delays creates a $4.2 billion annual economic gain, net of the value of the trips foregone. This structure of tolls would raise a total $44 billion per year in revenues, mostly collected on major arteries, without imposing any excess burden on the economy. Indeed, it would yield a net welfare gain. If these revenues were offset by reductions in distorting taxes that discourage labor force participation, savings, and other socially desirable behavior, economic productivity would rise.

In the mid-eighties, in the United States, the average vehicle occupancy rate for automobiles was 1.70 passengers for all travel (Davis et al., 1989) and only 1.15 passengers for commuting travel (Pisarski, 1987). In this study, only the costs of time delay to the driver were taken into account, but, of course, other passengers are equally penalized. For example, if a vehicle stuck in traffic contains two people then the time cost doubles. Therefore this analysis could be adjusted to take the average number of commuting passengers into account by raising the value of time by 15 percent. Doing so would increase optimal tolls, revenues generated, and welfare gains. In short, the results in Table 12 present only a lower bound on the possible welfare gains and revenues that road-use pricing could generate.

D. Other Costs

If other costs attributable to congestion are taken into account, the optimal tolls, the reductions in congestion, the net economic gains, and the revenues all increase. For example, the second row in Table 12 shows the results of incorporating the social costs of increased accidents in the calculation of congestion tolls. A conservative estimate of this cost is $0.10—$0.13, or 52 percent of private marginal costs. (Newberry, 1988) This is much lower than the estimates discussed above, which ranged from 1.5 to 2 times the average cost. However, the exact relationship between congestion and accident costs is uncertain. More accidents occur when traffic is heavy, but these low-speed, low-impact accidents cost less per accident in damages to property and persons. High speed accidents, by contrast, typically involve a higher probability of fatalities and greater overall damage costs. Since there is no direct empirical relationship between the costs of accidents and the level of congestion, average cost (private marginal cost) and social marginal cost were assumed in this study to diverge by a constant amount. Since drivers do not consider that by entering a roadway they are increasing the probability of an accident, the private marginal cost curve does not shift. Internalizing these accident costs requires a toll of ten cents per vehicle mile travelled over all levels of congestion, compared to the average fuel tax in 1989 of $0.011/vehicle mile.

The results in the second row of Table 12 are cumulative: they include the traffic reductions and revenue generated by the congestion toll and accident tax. If both are included, the total toll on a ten-mile urban trip would be up to $2.80, inducing an overall 8.4 percent reduction across all roads from the original traffic volume. Adding an accident tax increases the original amount of revenue generated to $73 billion per year. Part of these tolls paid by drivers would be offset by lower insurance premia as accident costs fell. In addition, the gain in welfare achieved by reducing traffic and accident casualties rises to $7.3 billion dollars a year. This is again net of the value to drivers of trips foregone because of higher tolls.

A related external time cost captured by this model was the external cost of time lost to accidents and breakdowns by those not directly involved. Traffic pile-ups behind accidents and vehicle breakdowns and associated "rubber-necking" delays rank among the most galling of the urban commuter's vexations. Although these incidents are not as inevitable as the morning rush hour, FHWA studies based on traffic simulation models and probability theory have predicted their frequency. (Lindley, 1987)

Some 200 hours per million vehicle miles are wasted during such incidents on roads with shoulders and 79 on roads without shoulders. Statistical regression analysis indicated that each additional VMT above a V/C of 0.7 can be expected to result in an additional 1.5 minutes of delay due to traffic incidents.

These results, although derived through a different methodology, lend themselves to the analysis of congestion costs. In this study, the same value of time spent in travel was applied to the estimates of delay to derive the private and social marginal costs of incident delay. Added to other cost elements, these higher external costs lead to a third estimate of optimal congestion tolls. Each VMT at or above a V/C (volume to capacity ratio) of 0.7 should be charged an additional toll of 12 cents per mile to internalize the costs of delay due to extra traffic incidents.

Over all urban highways, tolls would range from $0.10 to $0.36 ($3.60 for the typical ten-mile trip). Peak congestion would fall by more than 22 percent. Net welfare gains, including the value of time saved and traffic casualties averted, would exceed $10 billion per year on revenues of $98 billion nationwide. As various costs associated with traffic congestion are internalized, the net welfare gains rise relative to the revenues collected.

E. Projections to 1999

The results of this study suggest that considerable reductions in congestion as well as economic savings can be achieved now if tolls are used to control peak-traffic flows. But, what of the future? If present trends continue through the end of the century, most U.S. cities will face severe traffic jams much of the time. Can measures to control peak demand help avert this crisis?

For this analysis, past trends in vehicle miles travelled, capacity growth, and congestion levels were used to project the conditions that would occur in 1999 should these disturbing growth trends continue. For example, the growth rates in vehicle miles travelled, estimated from the past ten years of data, ranged from 6.2 percent for interstates to 2.4 percent for collector roads, while capacity on various road types has grown from 1.2 to 2.3 percent. A 6.2-percent growth rate means that in a little over 11 years, the vehicle miles travelled on interstates will double. Both the growth rate in VMTs and their distribution across roads and time spell bad news for urban drivers on interstates. In 1989, 30.8 percent of the VMTs occurred at a V/C level greater than 0.95—bumper to bumper traffic. By the year 1999, at least half will be. In 1989, over half (52.6 percent) of all travel on urban interstates was under severely congested conditions (V/C > 0.70). This percentage is expected to increase to 79.7 percent in 1999 if current growth rates continue. Almost 8 out of every 10 miles travelled on urban interstates will be in heavy traffic by the turn of the century. The same dreary prognosis holds for other freeways and expressways, on which the growth rate in VMT is 4.1 percent and that of road capacity is 1.2 percent. The percentage of travel at the most congested levels is estimated to grow from 38.0 percent in 1989 to 54.7 percent by 1999. For the other three categories of roadways, traffic is also growing much faster than capacity, indicating heavier congestion in the future: the growth rates for vehicle miles travelled and road mileage are 4.3 percent and 1.6 percent for other principal arteries, 3.8 percent and 1.6 percent for minor arteries and 2.4 percent and 1.5 percent for collector roads.

The analysis performed on the 1989 data was repeated with these estimates for 1999. As Table 13 shows, overall VMT is expected to grow from 1,055,637 million miles annually to 1,661,724 million miles annually between 1989 and 1999. Using the optimal tax policy for the three externalities discussed would reduce VMTs overall to 1,452,054 million miles in 1999—a 12.6-percent reduction in the projected levels of future vehicle miles travelled. Vehicle miles travelled under heavily congested conditions would be reduced by 23 percent. This

policy would generate revenues of over $178 billion dollars annually (in 1989 dollars) and a net welfare gain of $21.3 billion. Congestion tolls are an increasingly powerful tool for averting gridlock on urban highways.

F. Other Considerations

Given their potential effectiveness, why have congestion tolls never been adopted in the United States? Why is there so little experimentation with them even now? In 1976, then Secretary of Transportation Coleman invited mayors of several U.S. cities to host DOT-funded demonstration congestion toll projects. Most mayors turned down the offer. Typical was Atlanta's response: "...the city should not participate...due to potential practical, technical, political and financial problems." (Higgins, 1986) Projects were considered in Berkeley, California; Madison, Wisconsin; and Honolulu, Hawaii, but no demonstration projects came about, mostly because there was no political support for them.

The idea is unpopular because congestion tolls are thought to be an intrusive, inconvenient, regressive tax for the use of roads for which taxpayers have already paid at the gas pump, as well as through property and income taxes. Congestion tolls would indeed raise total travel costs for some motorists—those whose value of time is relatively low, and those who use competing toll-free roads that become more congested for instance. Although the gains from a properly designed system would substantially exceed such losses, some of the toll revenues should definitely be used to compensate those who lose under a new toll-based system. (DOT, FHWA, 1992) Indeed, revenues could be used to improve public transportation options, or to reduce other kinds of taxation. As noted earlier, popular support for the congestion toll concept is much higher when it is part of a financial package including program or tax-relief proposals for using the revenues. (Small, 1992)

If the revenues they generate are offset by reductions in other taxes, congestion tolls can readily be made revenue neutral. A tax package of this kind can also be designed to avoid inequitable burdens on lower-income households or other hard-hit groups. A study of the distributional effects of congestion tolls (Small, 1983) showed that, depending on how the new revenues are used, congestion tolls can generate net benefits for *all* income groups. Put simply, the economic gains from reduced congestion would outweigh the burden of additional driving costs at all income levels. If the revenue generated were distributed equitably among the population, the driver with average income would enjoy a net gain of $135 per year, while those in the lowest income group would gain $96 per year. (Small, et al., 1989) Of course, the revenue generated could be distributed in various ways to achieve any equity goal.

Congestion tolls, like other environmental taxes, are also among the least costly and fairest ways for states facing unsustainable revenue deficits to raise additional revenue. Unlike conventional taxes, which impose an excess economic burden, congestion taxes increase economic productivity. In fact, congestion tolls are no more regressive than many other revenue options, including sales and excise taxes. Moreover, since the charge is directly related to the driver's contribution to a widely perceived social problem and drivers can reduce their payments by adjusting their driving patterns, congestion tolls are fairer than most taxes.

Many people fear that tollbooths would actually exacerbate traffic congestion or that electronic license plates would create a governmental record of each citizen's movements, a dangerous invasion of privacy. But old-fashioned pay-as-you-slow-down tollbooths have been replaced by a high-performing electronic technology that performs well, ensuring accuracy and convenience. As for privacy, electronic toll pre-paid cards ensure the drivers' complete anonymity.

The perception that congestion tolls impose "double" taxation arises because road users already pay gasoline taxes. But gas taxes by no

Table 13. Projected Results of a Nationwide Congestion Toll System: 1999

	Interstates Congestion Toll	Other Freeways and Expressways Congestion Toll	Other Principal Arterial Congestion Toll
Original VMT	503,122 (million annual)	183,915 (million annual)	502,525 (million annual)
Adjusted VMT	457,302 (million annual)	169,656 (million annual)	469,968 (million annual)
Percent Reduction	9.1	7.8	6.5
Toll Range	0–9 (cents/mile)	0–11 (cents/mile)	0–12 (cents/mile)
Revenue Generated	29.3 (billion dollars annual)	9.6 (billion dollars annual)	21.3 (billion dollars annual)
Most Congested VMT	400,988 (million annual)	100,602 (million annual)	184,929 (million annual)
After Toll	359,852 (million annual)	89,764 (million annual)	164,219 (million annual)
Percent Reduction	10.3	10.8	11.2
Welfare Gains	3.6 (billion dollars annual)	1.1 (billion dollars annual)	2.0 (billion dollars annual)
	With Accident Toll	**With Accident Toll**	**With Accident Toll**
Adjusted VMT	432,406 (million annual)	162,824 (million annual)	459,990 (million annual)
Percent Reduction	14.1	11.5	8.5
Toll Range	0–16 (cents/mile)	0–17 (cents/mile)	0–19 (cents/mile)
Revenue Generated	52.4 (billion dollars annual)	16.3 (billion dollars annual)	35.5 (billion dollars annual)
Adjusted Congested VMT	335,080 (million annual)	83,014 (million annual)	154,504 (million annual)
Percent Reduction	16.4	17.5	16.5
Welfare Gains	6.8 (billion dollars annual)	1.9 (billion dollars annual)	3.3 (billion dollars annual)
	With Accident Delay Toll	**With Accident Delay Toll**	**With Accident Delay Toll**
Adjusted VMT	405,219 (million annual)	156,239 (million annual)	450,627 (million annual)
Percent Reduction	19.5	15.0	10.3
Toll Range	0–24 (cents/mile)	0–26 (cents/mile)	0–27 (cents/mile)
Revenue Generated	77.9 (billion dollars annual)	22.8 (billion dollars annual)	46.7 (billion dollars annual)
Adjusted Congested VMT	307,894 (million annual)	76,429 (million annual)	145,142 (million annual)
Percent Reduction	23.2	24.0	21.6
Welfare Gains	10.6	2.9 (billion dollars annual)	4.9 (billion dollars annual)

means cover the full costs of road construction, maintenance, and associated public costs of the automotive transport system. (MacKenzie, Dower, and Chen, 1992) Moreover, those taxes do not address the peak-load congestion problem. If congestion tolls were fully implemented, the typical commuter round trip during the most congested hours would cost about $4.00 in tolls. But other driving costs would fall. For example, since there would be fewer accidents, insurance rates would be lower. Since less gas would be wasted, fuel costs would be lower. In

Table 13. (continued)

	Minor Arterial Congestion Toll	Collector Congestion Toll	Total Congestion Toll
Original VMT	343,437 (million annual)	128,725 (million annual)	1,661,724 (million annual)
Adjusted VMT	325,267 (million annual)	123,759 (million annual)	1,545,952 (million annual)
Percent Reduction	5.3	3.9	7.0
Toll Range	0–15 (cents/mile)	0–21 (cents/mile)	0–21 (cents/mile)
Revenue Generated	13.0 (billion dollars annual)	4.1 (billion dollars annual)	77.3 (billion dollars annual)
Most Congested VMT	77,617 (million annual)	16,091 (million annual)	780,226 (million annual)
After Toll	66,951 (million annual)	13,587 (million annual)	694,369 (million annual)
Percent Reduction	13.7	15.6	11.0
Welfare Gains	1.1 (billion dollars annual)	0.3 (billion dollars annual)	8.1 (billion dollars annual)
	With Accident Toll	**With Accident Toll**	**With Accident Toll**
Adjusted VMT	321,213 (million annual)	123,170 (million annual)	1,499,602 (million annual)
Percent Reduction	6.5	4.3	9.8
Toll Range	0–22 (cents/mile)	0–28 (cents/mile)	0–28 (cents/mile)
Revenue Generated	19.8 (billion dollars annual)	5.8 (billion dollars annual)	129.8 (billion dollars annual)
Adjusted Congested VMT	63,003 (million annual)	13,032 (million annual)	648,634 (million annual)
Percent Reduction	18.8	19.0	16.9
Welfare Gains	1.8 (billion dollars annual)	0.4 (billion dollars annual)	14.2 (billion dollars annual)
	With Accident Delay Toll	**With Accident Delay Toll**	**With Accident Delay Toll**
Adjusted VMT	317,370 (million annual)	122,599 (million annual)	1,452,054 (million annual)
Percent Reduction	7.6	4.8	12.6
Toll Range	0–30 (cents/mile)	0–36 (cents/mile)	0–36 (cents/mile)
Revenue Generated	24.6 (billion dollars annual)	6.8 (billion dollars annual)	178.8 (billion dollars annual)
Adjusted Congested VMT	59,160 (million annual)	12,461 (million annual)	601,086 (million annual)
Percent Reduction	23.8	22.6	23.9
Welfare Gains	2.5 (billion dollars annual)	0.6 (billion dollars annual)	21.3 (billion dollars annual)

addition, drivers on less congested roads would be saved a great deal of time and spared aggravation. If in place in 1989, a nationwide system of congestion tolls would have saved over 450 million hours of time lost in traffic jams over the course of the year. If in place by 1999, the system would save almost two and a half billion hours per year.

Drivers and non-drivers alike would also benefit from cleaner air. Many metropolitan areas, such as Southern California, chronically

violate Clean Air Act ambient air quality standards, and face stringent, expensive, and wideranging "command-and-control" abatement requirements. These requirements could, some observers fear, retard industrial development, dictate transportation policies, and hamper economic development in non-attainment areas. Reducing road congestion, desirable in itself, would improve air quality substantially. For example, adopting the system of road-use pricing suggested in this report would reduce the pollutants listed in Table 14.

Table 14. Pollution Reduction ('000 metric tons)

Pollutant	1989 Reductions	1991 Reductions
Particulates	110	210
Sulfur oxides	60	120
Nitrogen oxides	60	1,200
Volatile organics	470	930
Carbon monoxide	3,350	6,600
Lead	240	—

Source: Based on WRI calculations.

Consider the alternative. If congestion tolls are not introduced to reduce peak-traffic volumes, what would be the cost of increasing road capacity to achieve the same improvement in congestion? In other words, what would it cost to increase highway capacity so that traffic was no more congested in 1999 than it was in 1989 even though the number of vehicle miles would increase? That is, how much would it cost just to prevent the current situation, already bad enough, from getting worse? The answer: almost $50 billion dollars in additional capital expenditures, just to increase capacity. This huge price tag is purely additional. It does not reflect the fact that most of our roads and bridges are deteriorating now and have to be repaired or replaced just to keep highway capacity the same. Therefore, congestion tolls would save the federal and local governments the immense cost of increasing capacity, while generating many billions of dollars in revenue for use by governments, possibly to pay for the deferred maintenance of the United States' existing transportation infrastructure.

The political prospects for congestion tolls now looks brighter. In the 1991 Intermodal Surface Transport Efficiency Act, Congress relaxed restrictions on the use of tolls on federally financed projects and authorized the expenditure of $25 million annually over ten years to establish, maintain, and monitor congestion-pricing pilot programs in cooperation with state or local governments. At the state level, in regions facing severe transportation and air pollution problems, the possibility of road-use pricing has become a reality. (Cameron, 1991; Elliot, 1986; Poole 1988) New interest in congestion pricing should come as no surprise. What other transportation policy would reduce congestion, raise economic productivity, decrease pollution levels, preserve drivers' freedom of choice, save governments the construction costs of increasing capacity, and, as an extra bonus, generate significant revenues in a way that imposes no excess burden on the economy?

IV. Carbon Taxes to Reduce CO_2 Emissions

The combustion of fossil fuels to power homes, factories, businesses, cars, and trucks results in the discharge of a wide array of pollutants into our environment. While several of the pollutants from the burning of fossil fuels—among them, sulfur dioxide (SO_2), volatile organic compounds, particulates, and nitrogen oxides (NO_x)—are regulated by federal, state, and local governments, one major pollutant, carbon dioxide (CO_2), remains unconstrained. Unfortunately, man-made emissions of carbon dioxide are the leading cause of the build-up of greenhouse gas emissions, which trap heat and intensify the natural greenhouse effect and may warm Earth's atmosphere. In the United States, most of the carbon dioxide released during human activities, some 1.5 billion U.S. tons of carbon per year, is emitted when fossil fuels are burned.

Carbon dioxide emissions have no immediate effects on health and the environment, and their full environmental impacts take decades to unfold. But while scientists continue to debate the timing, degree of risk, and environmental impacts of global warming, consensus is solidifying that average global temperatures are likely to increase as atmospheric concentrations of greenhouse gases rise, and it is already clear that the environmental risks are potentially large and diverse. The local physical effects of increasing temperatures might include coastal erosion due to sea level rise or drought due to changing weather patterns. The ecological effects may include the loss of wetlands and numerous species or, if they can't adapt fast enough as climate zones move, even entire ecosystems.[1] On the other hand, moderate levels of warming may entail some beneficial environmental impacts. No boons should be anticipated, but, for example, crop yields for certain plant varieties might increase as a result of increased CO_2 fertilization.

All of these changes ultimately have economic and political ramifications as well. Even if, for example, efforts are made to adapt to climate change by building coastal defenses, the costs associated with the loss of agricultural and fisheries harvest, coastal-based tourism, and other economic activities, as well as the need for new water supply and drainage systems and so on, may be painfully high. Then too, many of the world's poorest people live on coastal or marginally productive lands and could be forced to migrate, perhaps triggering economic and political instabilities.

Many long-term energy forecasts or projections conclude that without policy intervention, carbon dioxide emissions are expected to grow both in the United States and worldwide due to population growth, economic growth, and increased reliance on coal. (EIA, 1990) For example, the National Energy Strategy estimates that, in the absence of policy changes, U.S. energy use will increase by 64 percent by 2030. Coal, which now accounts for 22 percent of total energy use, will increase to 38 percent in 2030. This projected trend is even more

pronounced for other regions of the world. Scientists warn that avoiding unprecedented rates of climate change requires reversing this upward trend. The 1988 Toronto Conference suggested reducing carbon dioxide emissions by roughly 20 percent from current levels within a decade and making larger reductions thereafter. ("The Changing Atmosphere," 1988)

A. Defining a Carbon Tax

Any serious effort to reduce atmospheric concentrations of greenhouse gases will involve reducing CO_2 emissions.[2] This is not a simple problem. Carbon dioxide is emitted from millions of individual sources, ranging from cars and trucks to huge electric utilities. Fossil-fuel use is affected by consumer choices about how much heat, light, and other energy services they want to consume, how efficient their appliances are, and which type of energy their appliances use. Consumers also choose which non-energy goods and services they want to buy, and since some goods require more energy than others to make, they indirectly influence how much energy is used in manufacturing. For their part, manufacturers can typically choose whether to use relatively more labor and capital or relatively more energy in production, and they too can choose among energy types. Electric utilities can choose which fuels to use in generating power and, in many states, can also choose to buy or subsidize energy-efficient products for their consumers rather than to generate more power. Still another variable is whether consumers, manufacturers, and utilities will replace their energy-using equipment if energy prices change or wait until they have to buy new equipment anyway.

Clearly, for each source, options for reducing CO_2 emissions are diverse. Cars can be driven less, driven more efficiently, or designed more efficiently. Industries that emit CO_2 can use less coal and more natural gas, invest in energy efficiency programs, change their mix of products, or do all three. All these options and opportunities are likely to have different costs.

The most direct application of the concept of environmental charges to climate change risks associated with carbon dioxide would be to tax the emissions of CO_2 from individual sources. But it can't be done. The administrative and enforcement costs of imposing and collecting charges on the huge number and wide variety of sources would be overwhelming and likely to outweigh the economic benefits of using taxes rather than other policy instruments. Fortunately, the carbon content of the fuels that generate CO_2 when burned can serve as the tax basis without distorting the economic incentive that the charge represents. This is true for two important reasons. First, virtually all of the carbon in fossil fuels is released during combustion as carbon dioxide. (A potentially important exception involves uses of oil, gas, or coal that go directly into products without being burned.) Second, there is no technically and economically feasible way of removing CO_2 from the emissions of a combustion process the way, say, that sulphur dioxide can be "scrubbed" from the emissions of a coal-fired power plant. Thus, it is fair to assume that the carbon in a ton of coal, a barrel of oil, or a thousand cubic feet of natural gas, which is easily measured, will be released as CO_2 upon combustion. A charge on the carbon content of fuel is thus equivalent to a charge on emissions.

Following this logic, a carbon tax is defined as an excise tax on the producers of raw fossil fuels (sometimes called primary energy) based on the relative carbon content of the fuels. Such a tax would thus fall more heavily on coal than oil, which in turn would be taxed more than natural gas. *(See Table 15.)* To be most effective, the tax would be applied at the point that the fuel enters the economy—at the wellhead for natural gas, the minemouth for coal, and the well or dockside for oil. This approach keeps points at which the tax would be assessed and collected to a manageable number. It has the further advantage of taxing carbon early in the production chain and thus influencing all decisions concerning fossil fuel use.

Table 15. Carbon Content of Selected Fossil Fuels (lbs of Carbon)

	By Volume	By Energy Content (Btu)*
Coal	1440.00 (ton)	2.04
Crude Oil	6.18 (gallon)	1.60
Natural Gas	0.03 (1000 ft^3)	1.20
Gasoline	5.10 (gallon)	1.50

*(units are represented as 10^{-4} lbs per Btu)

Carbon taxes would appear to consumers and manufacturers as energy price increases. But since taxes would be levied on primary energy, which represents only one part of the cost of delivered energy (such as gasoline or electricity), and, more important, since one fuel can in many cases be substituted for another, overall price increases will not be as large as the initial tax. Consumers can respond to new prices by reducing energy use and buying fewer carbon-intensive products (those, for instance, that require great amounts of carbon-based fuels to produce). In addition, some of the money not spent on such products could be used to buy other less carbon-intensive goods and services.

The relative cost-effectiveness of any CO_2-reduction mechanism depends heavily on how comprehensively it covers the wide range of carbon sources and the flexibility it allows regarding the selection of the least expensive way to reduce emissions. These two factors are important for any pollution-control strategy, but especially for carbon dioxide emissions because the individual contributing sources of the pollutant are so numerous and varied. Taxes encourage a wide range of market responses to reduce emissions and the least costly reductions are usually undertaken first. As applied to CO_2 emission reduction, taxes offer significant advantages over alternative control strategies, even other market-based programs such as emission trading. Comprehensiveness and flexibility are two. But, three others—administrative costs, certainty of reductions, and adjustment costs—are important.[3]

• *Comprehensiveness.* If a carbon tax were applied to each fuel at the point where it is produced or imported into the United States, it would influence virtually all of the downstream energy choices of producers and consumers of carbon-based fuels, from electricity production to the use of cars. If imported energy-intensive goods were also taxed according to roughly how much carbon was involved in their production, the tax's coverage would be even more comprehensive. The tax would initially fall, however, on the comparatively few companies involved at this early stage in energy production.

Carbon taxes would appear to consumers and manufacturers as energy price increases. But since taxes would be levied on primary energy, which represents only one part of the cost of delivered energy (such as gasoline or electricity), and, more important, since one fuel can in many cases be substituted for another, overall price increases will not be as large as the initial tax.

• *Flexibility.* Unlike most regulatory programs, market-based programs, such as pollution taxes, can be adapted to changing market conditions, and they allow the least expensive reduction options to be undertaken first (provided that they achieve complete coverage of the different CO_2 sources). A carbon tax, however, could have one advantage here over, for instance, a trading system: it may be easier to

adjust the level of the tax (and, thus, emission reductions) to new information on costs and benefits. With a carbon tax, raising the rate increases the level of control. In a permit system, the number of permits available or the amount of emissions covered by each permit has to be reduced—potentially much more difficult politically. Once allocated, permits will be viewed as a form of wealth or private property, and reducing the emissions allowed under each permit would reduce the value of the permits.

• *Administrative Costs.* The cost-effectiveness of any market-based approach to controlling CO_2 emissions can be eroded if administrative costs are too high. Certainly, a carbon tax would entail a new collection burden for tax authorities, but since many of these fuels are already taxed at the federal or state level, entirely new entities would not be needed to impose, implement, or enforce the tax code changes. Indeed, virtually all of the data needed on fossil fuel consumption for tax purposes is already collected by various agencies. Other economic incentive systems would require setting up new national market structures.

• *Certainty of Reductions.* Does the relative uncertainty of emission reductions associated with a tax favor other economic-based approaches to CO_2 reductions, as some analysts suggest? In the context of dealing with climate change risks, the trade-off between lower control costs and somewhat less certainty over year-to-year CO_2 emission levels can be justified. Neither the costs nor the benefits of reducing human-caused climate change can be calculated with certainty. Typically, economists argue that taxes make more sense than alternative control strategies that directly limit pollution levels when the potential economic risks are high (if also uncertain) compared to the environmental risks. Conversely, controlling quantities of pollution makes more sense when the potential environmental risks (even if uncertain) are greater compared to the economic costs. According to this logic, policies appropriate for highly toxic or acutely dangerous environmental contaminants may not be as reasonable in efforts to minimize climate change. The risks of climate change are real, but they are not as immediate as the potential costs of control. Yet, some economic risks have to be accepted today to avoid potentially significant environmental risks in the future. Prudent public policy dictates a control strategy with near-term economic risks that can be easily managed.[4]

B. Setting the Right Level of a Carbon Tax

The higher the cost of fossil fuels, the less they will be used to produce goods and services, and the less carbon dioxide will be released into the atmosphere as a result. But how much reduction is enough? How big should a carbon tax be? If environmental considerations alone are the measure, the ideal tax rate is one set at the point at which the benefits from the last ton of carbon removed equal the added cost of eliminating that ton. But this point is notoriously difficult to find, especially for benefits that may be many generations in the future or for situations in which the science or relative risks are not completely understood. This number cannot be calculated until emissions are translated into atmospheric concentrations; until the effects of increased concentrations on the rate and level of warming are estimated; until the environmental and economic impacts or injuries associated with the warming are assessed, and until a dollar value is placed on the estimated damages. As is the case for many pollutants, researchers simply don't know enough yet to perform the initial calculations.

Preliminary efforts have been made to assign a dollar value to a small set of potential environmental risks associated with climate change, including loss in agricultural production. The most widely quoted of these estimates finds economic damages from a doubling of atmospheric CO_2 concentrations in the range of 0.5 percent of GNP for the United States.[5] But early estimates like these must still be considered

largely speculative. They are also likely to be conservative since many categories of potential environmental loss that could far outweigh more direct economic losses have yet to be quantified at all. For instance, some scientific consensus is forming that damages to unique or particularly sensitive ecosystems from rapid climate change constitute especially important environmental risks, but no damage estimates take the potential economic costs of such losses into account.

In a recent analysis of the economic damages in the United States from climate change, William Cline suggests that more inclusive estimates may be in the range of 1 to 2 percent of U.S. gross domestic product, or around $60 to $117 billion annually. The low end of this range would imply that the optimal carbon tax should be set at around $50 per ton of carbon. Cline also notes that these estimates do not consider the economic losses associated with atmospheric CO_2 concentrations that go beyond a twofold increase, even though atmospheric concentrations would almost certainly pass the doubling point if no efforts are made to reduce CO_2 emissions. He estimates economic damages from global warming in their very long-term to be around six percent of U.S. G.D.P. or approximately $340 billion annually. None of these estimates include values for direct consumer losses from climate change, such as the discomfort of more frequent heat waves or the inconvenience of more rainy and overcast days. (Cline, 1992)

The most common alternative method of determining the size of a carbon tax is to estimate the tax level necessary to achieve a preselected level of CO_2 emissions. (While concentrations are the key environmental indicator, emissions must be reduced to lower atmospheric concentrations.) For example, a tax can be chosen to stabilize emissions at 1990 levels by the year 2000. (This approach is used in a current legislative proposal. *See Box 1.*) This approach avoids the difficulties associated with explicit assessments of economic damages from climate change. It does raise other concerns, however. Most prominent among these is that the "right" tax is difficult to predict and depends on the timeframe selected and the level of control required. The tax necessary to stabilize emissions at one level in the year 2000 may differ greatly from a tax to stabilize emissions at another in the year 2010 or 2020. This concern is not merely academic. Virtually all economic analyses of carbon-reduction possibilities suggest that substantial early reductions, say over the next 10 or 15 years, can be achieved quite inexpensively. If so, a fairly low tax would be sufficient if levied soon. But as time goes on, sustaining or extending these reductions may become harder and harder, requiring a significantly higher tax. Eventually, of course, once a non-carbon based backstop technology becomes economic, no further increase in tax rates is required to reduce emissions. In the very long run, tax rates could actually be reduced.

C. Economic Consequences of Carbon Taxes

A properly set pollution tax generates net gains in overall social welfare through the environmental improvements it creates, regardless of its fiscal implications or its impact on official GNP estimates. Nonetheless, concerns about the economic consequences of pollution taxes abide. Carbon taxes are especially controversial because they have economy-wide effects. Even if the environmental benefits justify the costs associated with a carbon tax, policy-makers must have a clear idea of what these costs are likely to be. Specifically, they need to know the potential impact of a carbon tax on the production of goods and services, as well as who pays or bears the burden of the tax.

1. Macroeconomic Impacts of Carbon Taxes

Numerous studies have estimated the macroeconomic consequences of carbon taxes designed to reduce CO_2 emissions to various levels. The studies differ significantly in both approach and results, but most models suggest that the

Box 1. The Stark Carbon Tax Proposal

Representative Stark (D.CA) has introduced a proposal that illustrates the basic concepts of a carbon tax. H.R. 1086 is based roughly on a carbon tax option prepared by the Congressional Budget Office (CBO). It calls for a phased-in tax of $30 per ton of carbon in coal, oil and natural gas. According to the CBO, a tax of this magnitude might stabilize emissions of CO_2 at current levels by the year 2000. (This assessment does not assume a phased-in tax schedule.) Table 16 presents the proposed tax rate by fuel type for the phase-in period. In Table 17, these rates are expressed as the estimated percentage increase in the price of the taxed fuels. H.R. 1086 keeps the real tax rate fixed by allowing it to rise with the rate of inflation.

Table 16. Proposed Carbon Tax Schedule of H.R. 1086

	Carbon ($/ton)	Coal ($/ton)	Oil ($/brl)	Nat. Gas ($/tcf)	Estimated Revenue ($ bill)
Year 1	6	3.60	0.77	0.10	7
Year 2	12	7.20	1.54	0.19	14
Year 3	18	10.80	2.31	0.30	21
Year 4	24	14.40	3.09	0.40	28
Year 5	30	18.00	3.85	0.48	36

Table 17. Estimated Affect on Fuel Prices of H.R. 1086 Carbon Tax Proposal

Tax as a % of Price	Coal	Oil	Natural Gas
Year 1	16	4	4
Year 2	31	8	8
Year 3	47	12	12
Year 4	63	16	16
Year 5	78	19	19

economic consequences are likely to be either fairly small losses or outright gains.

Since a carbon tax makes fossil fuels more expensive, it will alter the use of capital, labor, energy, and other economic resources. In response, businesses and households will try to lower their tax payments by reducing their use of fossil fuels and increasing their use of capital, labor, and non-fossil energy. Consumers might respond to higher electric prices by buying more efficient appliances or using the ones they have less. Utilities might increasingly make electricity with energy sources that emit little or no carbon (biomass and wind or solar power). The net effect of these switches will be to reduce the production of some goods and services. Under these circumstances, projected GNP would be expected to fall, reflecting the net impact of these changes on overall market prices and household expenditures. The negative GNP estimates presented in many early studies of carbon taxes demonstrate this set of first-order effects.

The way the revenues from the carbon tax are used, however, changes the picture dramatically. The ranges for GNP effects presented in

Table 18 represent the impact of different revenue recycling options—for example, reducing the tax rate on capital, labor, and personal income taxes. By reducing the price of using capital and labor, these tax changes thus potentially improve economic performance. In fact, the projected economic advantages from the revenue recycling more than compensate for any direct GNP loss associated with the carbon tax.

2. *Recycling the Revenues*

The macroeconomic simulations reported in Table 18 differ on a number of important bases. Changing the assumptions concerning, for example, future paths for economic growth and energy consumption, as well as possibilities for the substitution of one energy input for another, produce very different results, even from the same model. (Many of these differences are explored in more detail in an earlier WRI report on carbon taxes.[6]) One critical finding, however, is central to the theme of this report: these modelling results show that using pollution tax revenues to lower other distortionary tax burdens can improve the nation's economic performance.

The large revenue streams generated by a carbon tax can have economic effects much larger than those triggered by changes in relative prices. Such impacts will vary, depending on how the revenues are used. The studies presented in Table 18 take two different approaches toward handling carbon tax revenues. They either (1) return the revenues to consumers in lump-sum reimbursements (by lowering personal income tax payments) or (2) reinvest them to promote economic growth by cutting the marginal tax rate on selected existing taxes.

Table 18 makes it clear that either reinvesting or recycling the tax revenues into the economy by lowering payroll or capital tax rates can at a minimum offset a significant portion of any estimated loss in GNP. If tax reductions are carefully targeted GNP stays the same or rises relative to what it would have been without the carbon tax. These results are consistent with the relatively large deadweight losses associated with current tax rates on capital and labor. More important, the economic gains from reducing existing deadweight losses outweigh any economic losses associated with reduced fossil fuel use. This possibility has been ignored in most studies of carbon taxes. Prior to the modelling effort reported in Table 18, carbon tax analyses evaluated specific types of tax cuts—such as personal income tax cuts—that had the least impact on reducing deadweight losses in the tax system. Using carbon tax revenues to cut personal income taxes, simply gives all consumers back a portion of the tax and fails to improve economic productivity. This approach might stimulate some short-term consumer

Table 18. Estimates of the Macroeconomic Costs of Reducing CO_2 Emissions Through a Phased-In $40 Per Ton Carbon Tax

Study	Change in GNP (%Δ from baseline)	Carbon Reductions in 2010 (%Δ from baseline)
Jorgenson-Wilcoxsin	−1.0 to 0.9	−22.8 to −22.3
Goulder	−0.4 to 0.0	−28.7 to −28.4
DRI Annual	−0.9 to 4.0	−6.6 to −3.2
Link	−1.1 to 4.0	−4.0 to 0.3

Source: Shackleton, Robert, et al. (1992).

spending, but it does little to overcome the basic inefficiencies of today's tax code and therefore to contribute to long-run economic growth.

Not surprisingly, the different models yield different answers concerning which tax reforms have the largest impact on economic performance. Internal model assumptions relating to the responsiveness of labor supply to changes in wage rates and the sensitivity of capital investment to changes in the costs of capital, dictate the degree of estimated economic distortions from existing taxes and thus the economic benefits of reducing these distortions. In general, the models agree that returning the revenues of a carbon tax to the economy through an investment tax credit has the biggest effect on GNP. By lowering the costs of new capital investments, such a credit spurs real growth in the national capital stock and increases estimated economic growth over what it would have been without the tax credit. Basically, an investment tax credit (ITC) reduces the existing tax burden on new capital.

In general, the models agree that returning the revenues of a carbon tax to the economy through an investment tax credit has the biggest effect on GNP.

An ITC has at least two other important economic implications. First, it essentially lowers the cost of capital relative to labor and could slightly increase projected long-run unemployment. Second, in several of the macroeconomic models, an ITC promotes enough economic growth to offset some fraction of the expected carbon dioxide reductions. This is particularly true in models that have a fairly inflexible link between economic growth and energy consumption and that reflect the assumption that there will be relatively few opportunities to switch to lower carbon fuels.

Many macroeconomic models suggest that the negative impacts of an ITC on estimated employment can be largely eliminated by combining the tax credit with reductions in income taxes or payroll taxes. For example, one set of simulations using the DRI model show that offering an ITC, along with reductions in personal income tax and employer payroll tax reductions can keep the GNP constant without causing any net loss in jobs.[7] Targeting some portion of the ITC toward investments in renewable energy sources and energy efficiency could help make increased growth less dependent on increased energy use (with the resulting CO_2 emissions). Although the impact on CO_2 emissions and economic growth of an ITC focused on new energy investments has not been carefully evaluated, using such a credit could help lower the transitional costs of shifting to lower carbon energy sources while still providing broad tax-reform benefits.

Any number of tax reform options could be financed through a carbon or other pollution tax. The choice depends on which public policy goals are considered most important. The simulations reported here illustrate the economic implications of just a few alternatives. The potential benefits of tax-reform initiatives coupled with pollution taxes are not limited to standard indicators of economic health; they also influence how economic wealth is distributed throughout the economy—a subject discussed more fully below.

3. *What the Models Miss*

The macroeconomic models that underlie the estimates in Table 18 can provide useful guidance on the pollution-reduction potential of various levels of carbon tax. But the picture provided by models is far from complete. An earlier report and Congressional testimony from WRI show how and why existing economic models tend to overstate the economic costs of various carbon taxes and to underestimate CO_2 reductions.[8] The opportunities for energy efficiency investments and technological innovation encouraged by higher energy prices,

for example, will (everything else being equal) make it possible to achieve any given reduction target with smaller taxes.

If the appropriate carbon tax rate has been selected, economic welfare should improve regardless of how the revenues are used because the economic losses from excessive greenhouse gas accumulation would be avoided.

A bigger shortcoming of existing models, however, is that they don't accurately portray the true welfare gains of a carbon tax (or any other pollution tax) coupled with tax reform. All of the macroeconomic models in Table 18 implicitly assume that a carbon tax is a distorting tax. In these models, the GNP impacts of the tax are reduced or eliminated by lowering even more distorting taxes, not as a result of any environmental benefits from a carbon tax. If the appropriate carbon tax rate has been selected, economic welfare should improve regardless of how the revenues are used because the economic losses from excessive greenhouse gas accumulation would be avoided. The tax reform benefits would then be additional gains to the economy not simply offsetting economic losses from imposing the pollution tax.

More important, changes in the national mix of energy sources and reductions in the use of fossil fuel would presumably reduce other pollutants as well—for example, sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide, heavy metals, hydrocarbons, and particulate emissions. A study by the World Bank suggests that the SO_2 and NO_x reductions alone resulting from a $26/ton carbon tax could be in the range of 2,766,000 tons.[9] For illustrative purposes, valued conservatively at $600 a ton, the economic benefits of these reductions might be in the range of $1.5 billion per year.

Accurate estimates of the non-CO_2 pollution benefits of a carbon tax are not yet available. Appraisal of such benefits for the United States is complicated since many of the pollutants are already subject to fairly stringent control requirements. In particular, SO_2 and NO_x, primary pollutants from coal combustion, are facing tight control under the 1990 CAAA: SO_2 emissions, for example, are capped at 10 million tons per year by the year 2005. A moderate stabilization level carbon tax probably won't reduce coal use enough to eliminate the cap as a binding restriction on SO_2 emissions. Of course, much higher carbon taxes (with higher CO_2-reduction targets) could reduce SO_2 emissions below the existing requirements. In any case, the environmental benefits should be included in any economic analysis of carbon taxes to ensure that net—not gross—costs get measured.

Along with direct environmental benefits related to CO_2 emission reductions, model specifications also miss other non-climate related benefits. For example, most of the economic models show that oil imports fall under a carbon tax. Such reductions would, of course, be associated with reduced threats to our national security and and might improve our international terms of trade. As for how much enhanced security might be worth, a study by the Energy Information Agency pegs the benefits of a $40/ton carbon tax at around $18.1 billion.

D. Distributional Consequences of Carbon Taxes

By nature, taxes—or any kind of revenue-raising measure—make some people worse off than they would have been without the tax. Indeed, as a practical matter, all forms of pollution-control programs affect somebody's wealth. The question is whether taxes have better or worse distributional effects than

alternative control strategies. Unfortunately, the distributional consequences of environmental programs do not receive the explicit attention they deserve, given their political importance. The distributional characteristics of environmental initiatives have always figured centrally in the design of environmental statutes and the selection of pollution-control programs. In fact, cost-effective control strategies have often been dismissed because their distributional effects were unacceptable. Yet, few distributional studies of pollution programs or pollution taxes have been conducted.

Carbon taxes, a recent exception, have been widely evaluated for their distributional consequences. But virtually all attention has been focused on the cost effects. No studies show how the damages from climate change would be distributed—a serious gap from the standpoint of the design of pollution tax strategies and tax-reform initiatives.

The perception that pollution taxes in general and energy taxes in particular are "unfair" has been perhaps the major barrier to their widespread application. Energy taxes have been roundly criticized as regressive, though other potential distributional impacts, both regional and industrial, have also sparked concern. These claims can't be evaluated accurately without accounting for the economic benefits of recycling carbon tax revenues. Except for industrial impacts, no studies of the distributional implications of carbon taxes take these economic effects into account. The current estimates, which are likely to overstate the regional and income-related impacts of carbon taxes, are thus best thought of as "worse case" analyses. Yet, any sound carbon tax strategy would include programs to compensate people adversely affected by the net impacts of a carbon tax, including cuts in other taxes.

1. The Impact of Energy Taxes by Income Class

Conventional wisdom holds that most forms of energy taxes discriminate against lower-income families and individuals. Because these groups spend a higher percentage of their incomes on energy than other income classes do, any tax based on energy—this logic goes—hits these groups disproportionately hard. But there is more to the story. The Congressional Budget Office and other researchers argue that different measures of wealth yield different measures of the burden of a tax.[10] In particular, the Congressional Budget Office and James M. Poterba of the Massachusetts Institute of Technology have shown that if a broader measure of wealth than income—actual expenditures—is used, energy taxes appear less regressive. (Expenditures represent a more stable long-run measure of wealth than income since they are less related to fluctuations in employment status or earning cycle. They also include government transfer payments, such as Aid to Families with Dependent Children (AFDC), which aren't normally included in income figures.)

Even if energy taxes cannot be called progressive, they may be less burdensome on the poor and middle class than commonly thought. With appropriate cuts in payroll taxes, these groups could actually come out ahead.

As Table 19 shows, the impact of a carbon tax is roughly proportional if expenditures are the measure. Even if energy taxes cannot be called progressive, they may be less burdensome on the poor and middle class than commonly thought. With appropriate cuts in payroll taxes, for example, which are generally considered highly regressive (at least in terms of first-order effects), these groups could actually come out ahead.

Other tax or spending reforms could be used to address any remaining inequities in the income effects of a carbon tax. These might

Table 19. Comparison of Estimated Distributional Impacts of a Carbon Tax by Alternative Measures of Income

Distribution Across Income Classes

Income/ Expenditure Decile	% of Income	% of Expenditures
1 (Lowest)	10.1	3.7
2	5.0	3.7
3	4.6	3.8
4	4.1	3.7
5	3.6	3.4
6	3.0	3.4
7	2.7	3.2
8	2.3	2.8
9	2.1	2.7
10	1.5	2.3

Source: Poterba, J.M. (1991).

include, for example, expanding the Earned Income Tax Credit, increasing food stamp benefits, or increasing the standard deduction.[11] None of these uses of the revenues from a carbon tax, however, would improve the efficiency of the nation's current tax system (as would lowering payroll tax rates.) Obviously, special programs may be required to help individuals who are outside the current federal tax system.

2. The Impact of Energy Taxes by Region

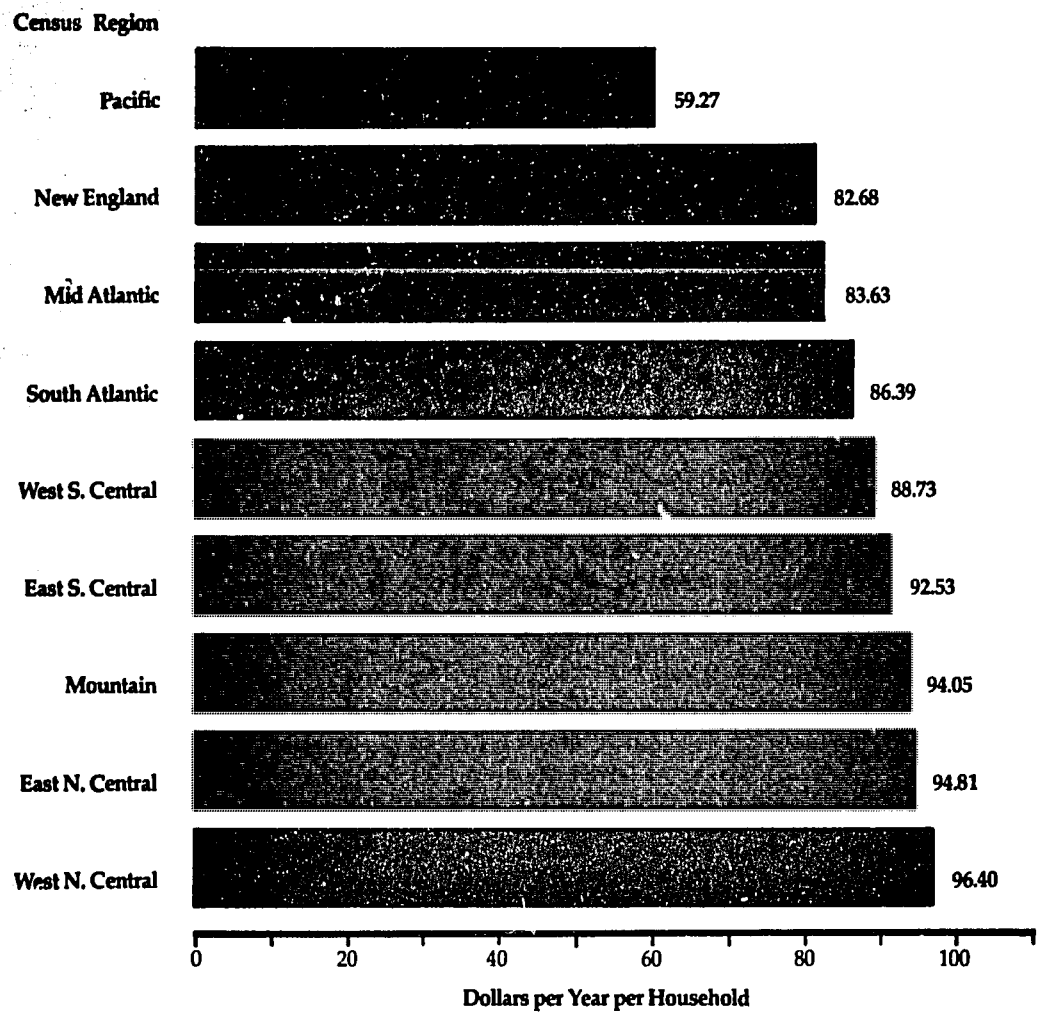
Energy taxes can redistribute a nation's wealth by region as well as along economic class lines. Because energy production, use, and cost vary by region, some parts of the country will bear a higher tax burden than others. Such potential regional effects can be measured in two ways. First, the tax directly affects energy expenditures by households in the region. The regional tax bill will depend not only on the tax rate, but also on consumers' ability to adjust their energy use in response to the tax.

The second measure is the indirect (or second-order effects) of the tax on a region's industrial activity, employment, and wealth. As taxes translate into higher energy prices and economic activity adjusts, regions with the most energy-intensive industrial bases may be put at an economic disadvantage relative to other regions. Both of these impacts—the regional expenditure effect and the regional economic effect—deserve policy attention.

A carbon tax would actually reduce regional energy price inequities.

• *Regional Expenditures.* D.E. DeWitt, H. Dowlatabadi, and R.J. Kopp of Resources for the Future have estimated the regional distribution of alternative carbon taxes.[12] As Figure 5 shows, differences among regions are neither great nor significant. The average household in New England would pay around 20 percent less in taxes than a household in the north-central states. With the exception of the Pacific Northwest, the regions with the highest added tax burdens are also the regions with the lowest electricity prices—a function of reliance on low-cost coal as an energy source. From these estimates, it appears that a carbon tax would actually reduce regional energy price inequities. Another key variable is households' ability to adjust their buying habits in response to the tax and to adopt, for example, more energy-saving products and processes. Estimates of regional expenditure rise by almost 15 percent if consumers are assumed to have few options for avoiding the tax. In a "conservation" case, in which the Resources for the Future researchers assume that consumers have more latitude, the absolute impact falls, though the regional differences remain. Unfortunately,

Figure 5. Estimated Changes in Residential Energy Costs from a Carbon Tax by Region



Source: D.E. DeWitt, H. Dowlatabadi, and R.J. Kopp, *Who Bears the Burden of Energy Taxes?*, Resources for the Future, Washington, D.C. (March 1991)

this scenario is not very flexible and may not accurately reflect the full range of economic responses after the tax has been in place for some time. Remember too that these estimates do not consider the impacts of recycling the tax revenues.

• *Regional Economic Impacts.* The relative economic wealth of states or regions can also be affected by carbon tax strategies. States that depend on carbon-based energy sources for generating income or that rely on carbon-based energy-intensive industries could be hurt disproportionately more by a carbon tax on energy than by another form of energy tax. Perhaps predictably, determining exactly how much a state's economy is affected is no simple matter. In the case of a carbon tax, for example,

oil, natural gas, and coal prices would rise, but simply multiplying the amount of the tax by the amount of the fossil fuel resource produced in the state is not a sound measure of economic damage. Instead, the impact of the tax on demand for fuels and, ultimately, on production levels must be traced.

Virtually all economic models show that a carbon tax has its greatest impact on coal production. By the same token, most of the reduction in oil demand would come from reducing oil imports. Thus, the wealth of oil-and natural gas-producing states would change little and much of the reduction in coal demand would come out of anticipated growth in coal use, not reductions in current levels of use.

Virtually all economic models show that a carbon tax has its greatest impact on coal production. By the same token, most of the reduction in oil demand would come from reducing oil imports.[13] Thus, for the level of taxes considered here, the wealth of oil-and natural gas-producing states would change little. Coal production does decline compared to what it would have been without the tax. Depending on the level of tax, however, much of the reduction in coal demand comes out of anticipated growth in coal use, not reductions in current levels of use. CO_2-reduction commitments beyond stabilization or 20-percent reductions are likely to require much deeper reductions in coal production.

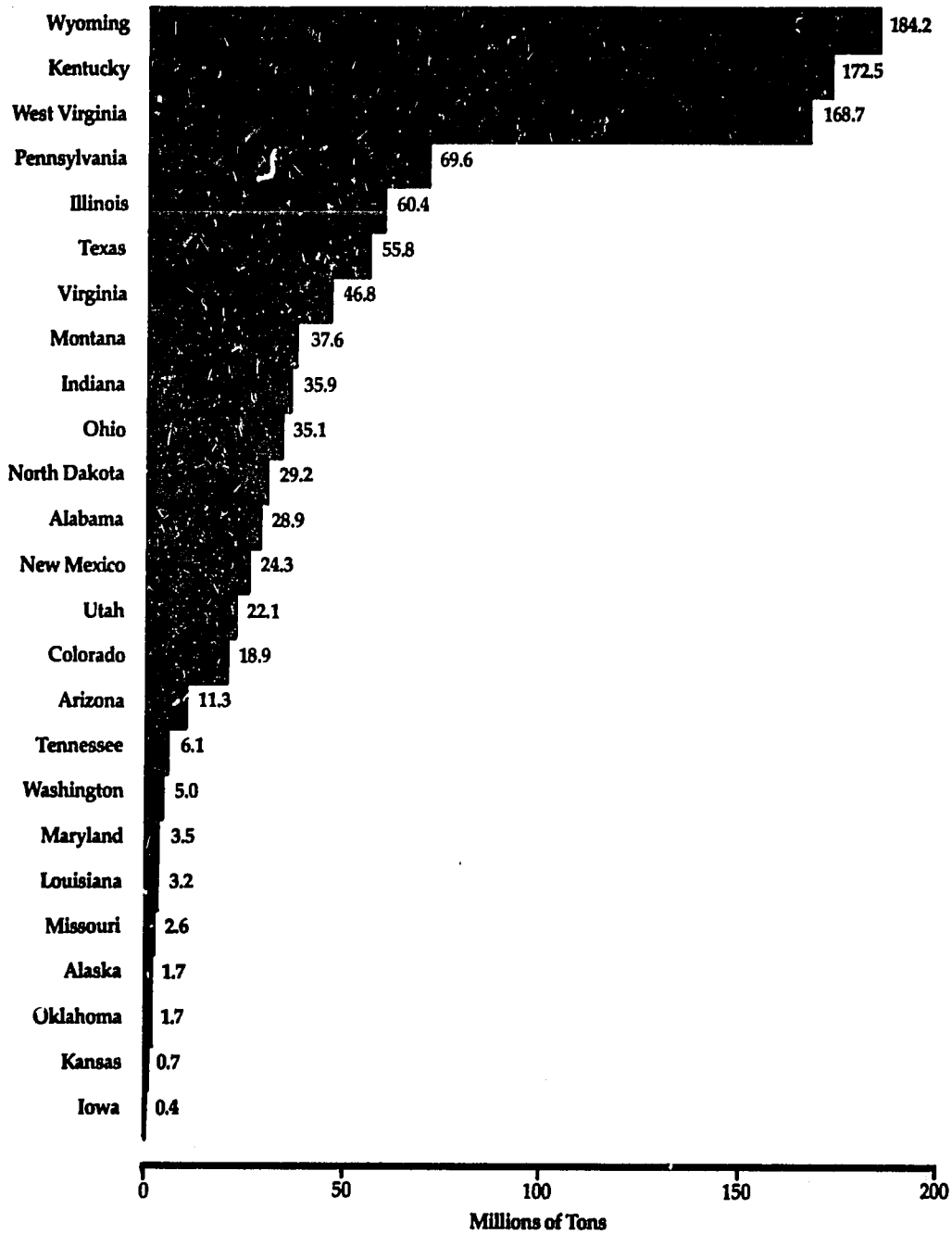
No published modelling results disaggregate energy tax burdens on specific industries at the state or regional level, so the degree to which the GNP effects of carbon taxes would be borne by any specific state or how coal production in Wyoming is reduced relative to that in West Virginia can't be specified yet. Still, the states at first-order risk are relatively easy to identify. As Figure 6 shows, Wyoming, Kentucky, and West Virginia which together account for over half of total U.S. coal production, would bear a significant fraction of the costs of lost growth in production.

The actual dollar loss to these three states is difficult to estimate; it depends, in part, on what would happen in the absence of a carbon tax. For perspective, coal-mining employment levels have been falling even though coal production has risen. Increased production of western coal (which is capital-intensive) and increased mechanization of eastern coal mines have already led to losses in the mining population, and many Appalachian coal regions are already amid an economic transition. Between 1980 and 1989, for example, coal employment fell by 43 percent to a total of 116,000 workers (in 1989), while coal production increased by approximately 30 percent.

Calculations of economic losses due to a carbon tax should take coal types into account too. Most carbon tax proposals assume implicitly that all types of coal contain the same amount of carbon, but they don't. Eastern bituminous coals can contain as little as 40 percent carbon or as much as 80 percent. Western sub-bituminous coal typically has lower percentages and less variation. A carbon tax based on an average carbon content will push coal users, everything else being equal, to pick coals with higher carbon contents (and generally higher energy values) than average since the price per unit carbon is the same.

These mitigating factors aside, carbon taxes as a whole do fall most heavily on coal production, and coal-producing states or sectors are likely to demand fair compensation for their losses. While a number of different approaches might be used to offset losses to coal-producing regions, a block-grant program may be

Figure 6. United States Coal Production by State, 1990



Source: Energy Information Administration, *Coal Production 1990*, EIA-0118(90), U.S. Department of Energy, Washington, D.C. (1991)

most appropriate, giving states the flexibility to design their own programs.

3. *The Impact of Carbon Taxes by Industry*

Not surprisingly, carbon taxes would fall most heavily and directly on the energy-production sectors—coal mining in particular—and on industries that depend on coal as well as other fossil fuels. As the initial price increases are passed on to final consumers (or back to shareholders), however, the economic burdens of the tax would spread to other industries and sectors. The ultimate first-order impact on the performance of any individual industry depends on whether that industry embraces energy efficiency, switches to fuels that are taxed less, or passes on the price increase to consumers or back to coal-production sources.

On the other side of the equation, some industries, of course, would benefit from the tax. Plastics recyclers, biomass producers (including both the agricultural and processing components), and solar power industries for instance, could all get a break, especially if the net economic gains associated with recycling the revenues from a carbon tax back into the economy are considered. The results presented earlier suggest that more industries will win than lose. Everything being equal, investment tax credits or lower corporate capital or labor tax rates would benefit many industries, particularly those in which energy represents only a small percentage of their overall production costs. Communication and information services, financial services, medicine, and other high-technology industries are likely to grow faster under tax-reform initiatives of this sort. Certainly, industries that offer low or no carbon energy services would also gain under a carbon tax coupled with a tax shift. On a national level, aggregate productivity and growth would rise.

Although it is difficult to estimate accurately the net change that a carbon tax would induce

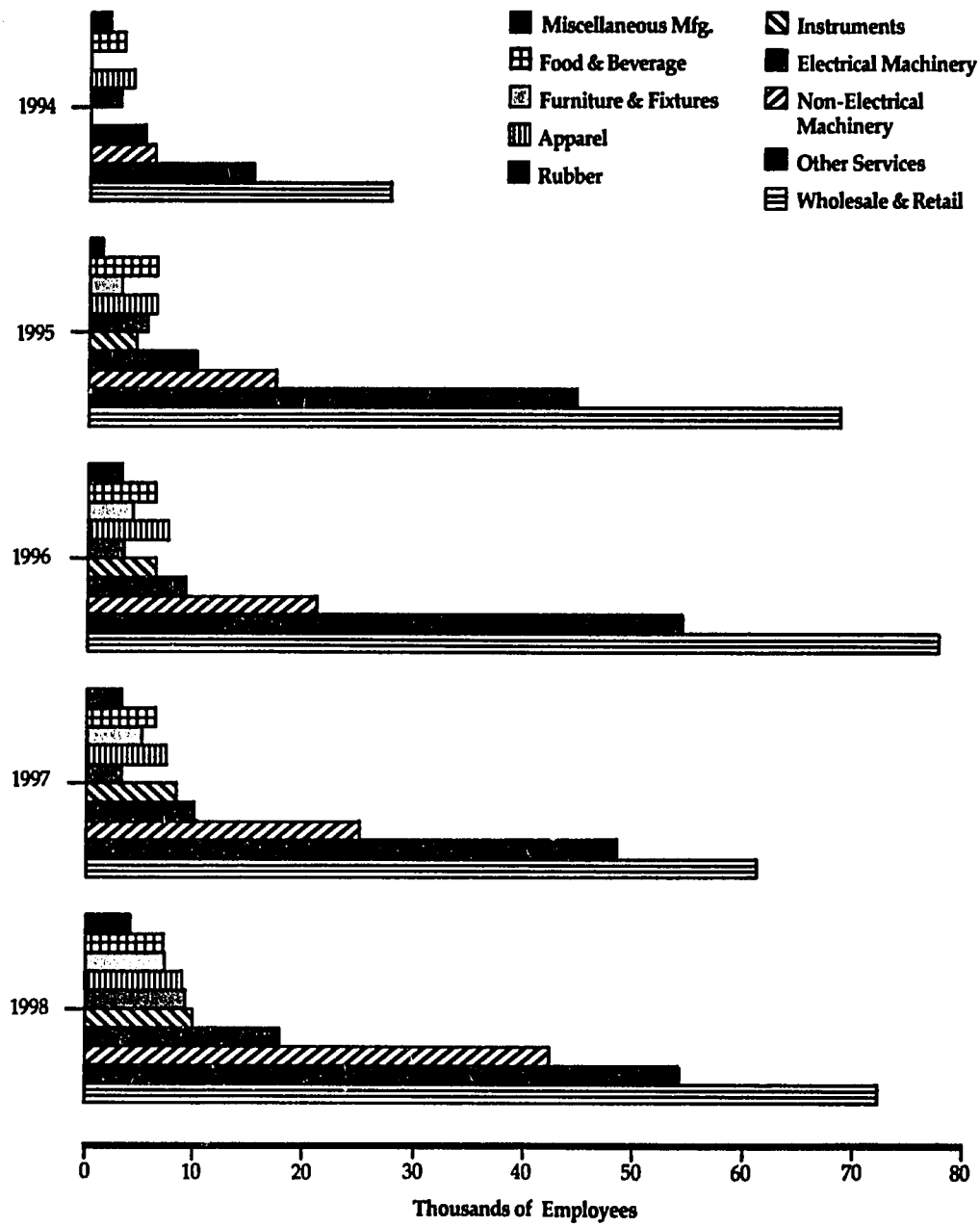
Communication and information services, financial services, medicine, and other high-technology industries are likely to grow faster under tax-reform initiatives of this sort.

in the economic activity of individual industrial sectors, recent preliminary studies by the U.S. Environmental Protection Agency show the potential for winners as well as losers. The estimated employment gains in industrial sectors that experience growth under a $40/ton carbon tax with revenues recycled through a combination of an ITC, payroll tax deductions, and personal income tax reductions are shown in Figure 7. This simulation was designed to keep GNP and employment unchanged from their levels in the absence of a carbon tax. Most of the shifts in economic activity are toward the services and wholesale/retail sectors, but the machinery and instruments sectors also improve. The point here is not to accept any specific estimate or number, but rather show that a carefully crafted pollution tax will increase economic activity in some sectors at the same time that others (with relatively high levels of pollution) may face economic losses.

E. The International Context for Carbon Taxes

Compared to the other pollution tax strategies considered in this report, carbon tax policies need to be considered in a broad international context. One reason for this is obvious. The Climate Convention, recently signed by over 150 countries at the Earth Summit in early 1992, requires all industrialized countries to adopt and enact limitation strategies together. The other reason is more subtle, but no less important. The potential for a carbon tax to

Figure 7. Output-Neutral and Employment-Neutral Stabilizing Carbon Tax: Industries with Employment Increases



Source: Yanchar, 1992. (Personal communication with Robert Shackleton, USEPA.)

affect the competitiveness in international markets of certain goods and services is already playing a major role in defining the debate over carbon taxes versus other emission reduction tools. The energy/carbon tax strategy proposed by the European Commission has been made conditional in the United States and other OECD countries adopting similar taxes mainly because of concerns over the impacts of unilaterally-imposed carbon tax on trade and competitiveness.

Of course, any serious effort to restrict CO_2 emissions will raise the price of carbon-intensive goods and services. To the extent that these products are important components of international trade flows, unilateral initiatives may well affect trade balances—whether or not one country has higher existing energy taxes than another. The potential impacts on trade flows of high-carbon goods has an important environmental dimension as well. Unilateral action may have the effect of transporting or "leaking" CO_2 emissions from one country or region to another. An EC-wide carbon tax, for example, might reduce EC emissions but prompt other OECD countries to generate more. Without doubt, there are clear barriers and costs to unilateral action on carbon taxes.

A carbon tax coupled with tax reform would create economic benefits for the United States even if it was unilaterally imposed.

This study suggests that a carbon tax coupled with tax reform would create economic benefits for the United States even if it was unilaterally imposed. The balance of trade in the United States might be further improved because the tax would lower the oil import bill. Trade losses could also be reduced by exempting various uses of carbon-based fuels or exempting key industrial sectors, as virtually all of the small number of carbon tax programs that have been enacted unilaterally in Europe do. While such exemptions may minimize the trade effects, they also lower the economic and environmental effectiveness of the tax, of course. Taxing imports of carbon-bearing goods might also be an alternative for minimizing the trade effects of a carbon tax, though the administrative costs are likely to be enormous.

The environmental, economic, and political realities of designing a carbon tax within an international context suggest that encouraging multilateral action entails fairly substantial benefits. An OECD-wide system of national carbon tax strategies would provide a basis for tax reform within individual countries (with different existing tax distortions) and remove the risk or fear of significant trade effects within the OECD. It would also limit the problem of leaking CO_2 emissions, at least within the OECD. (Under the Climate Convention only the industrialized countries are committed to making reductions anyway.)

In the longer run, the competitiveness of the United States relative to that of our major trading partners, as well as the competiveness of our trading partners, will be determined by the ability to improve and sustain the productivity of domestic workforces. Meeting this goal requires, among other things, an adequate capital investment. Coupling a carbon tax with broader tax-reform initiatives could create such incentives.

Just as important, some industries are likely to benefit directly from a carbon-reduction strategy. Producers of renewable-energy and energy-efficiency technologies comprise just one set of potential winners. Developing these industries domestically would spur opportunities abroad, especially as other nations pursue energy-efficiency and renewable-energy alternatives.

Notes for Chapter Four

1. A useful summary of the science of climate change and its potential risks can be found in IPCC (1990).

2. Worldwide, carbon contributes 66 percent of total Greenhouse gas emissions (weighted by extent of contribution to total warming), a number which is expected to increase over time. Carbon emissions constitute 53 percent of total U.S. emissions.

3. Some of these points are treated more fully in Parker (1991).

4. *See:* Oates, W.E. and P. R. Portney (1991).

5. *See* in particular, Nordhaus, W.D. (1991).

6. *See* Dower, Roger C. and M.B. Zimmerman, (1992).

7. Yanchar, J. (1992).

8. *See*, in particular, Dower, R.C. (May 1992).

9. Shah, A. and B. Larsen (1992).

10. Congressional Budget Office (1990), and J.M. Poterba (1991).

11. These proposals are discussed in more detail in Dower and Zimmerman (1992). *See also* Congressional Budget Office (1990), and Greenstein, R. and F.C. Hutchinson (1990).

12. DeWitt, D.E., H. Dowlatabadi and R.J. Kopp (1991).

13. Congressional Budget Office (1990), p. 32.

V. Other Potential Environmental Charges

Solid waste collection charges, congestion tolls, and carbon taxes are important examples of environmental charges, but they are by no means the only promising applications of the taxing power for environmental purposes. The U.S. government already employs a variety of fiscal mechanisms to promote environmentally desirable practices, to discourage environmentally damaging activities, and to fund environmental protection programs. Already in the tax code, for example, are tax credits for the production of ethanol and other renewable fuels, excise taxes on gas-guzzling automobiles and certain chemicals that deplete stratospheric ozone, and taxes on crude oil and imported petroleum products to finance the Oil Spill Liability Trust Fund and Superfund.[1]

Unfortunately, the federal tax code also contains many perverse provisions that promote environmentally damaging activities and discourage environmentally beneficial practices.

Unfortunately, the federal tax code also contains many perverse provisions that promote environmentally *damaging* activities and *discourage* environmentally beneficial practices. For example, farmers are allowed to deduct from taxable income part of the value of groundwater extracted for irrigation in excess of annual recharge, a provision that encourages depletion of the nation's aquifers and reduces federal tax receipts. (Ward et al., 1989) Or, to take another example, employers are allowed to provide free parking to employees as a tax-free fringe benefit, subject to dollar limits much higher than those on tax-free reimbursement on public transit commuting costs. This provision strongly encourages people to drive to work, exacerbating urban congestion and pollution. (Shoup and Wilson, 1992) Removing such environmentally perverse tax advantages is another potential application of the taxing power.

This chapter identifies many additional potential environmental charges and tax measures that would make environmental protection more efficient and raise government revenue with less distortion of the economy than conventional taxes create. Most have already been enacted and enforced by some state or local governments in the United States or by governments in some other countries.[2] They are not theoretical inventions, but workable instruments of public policy.

It's useful here to distinguish among various kinds of environmental charges. There are important legal distinctions between taxes and fees. Under the U.S. constitution, federal taxes must be legislated by Congress. The U.S. Environmental Protection Agency, therefore, cannot impose environmental taxes. Furthermore,

indirect taxes, such as federal excise taxes, must be uniform nationally, though rates may vary by relevant categories of the tax base. Most state constitutions have analogous provisions. By contrast, some fees authorized by statute can be set and collected by executive agencies to recapture the costs of public services provided, including the use of public lands, waters, and other natural resources. EPA and state regulatory agencies may, under various statutes, impose fees to fund program services and to support regulatory programs. Courts have upheld such fees even if the revenues exceed program costs and the rates are set to influence or deter activities. (Anderson, 1977, Ch. 5) These distinctions are legally significant, but taxes and fees can be designed to provide very similar incentive effects. The generic term "environmental charges" refers to both.

A simple classification of different kinds of environmental charges, such as that in Table 20, would distinguish charges on environmentally damaging *activities* from charges on *products* whose use entails environmental costs. Examples of the first include discharges of polluting wastes into air, water, and soil. Charges imposed on the basis of the volume and toxicity of such emissions are called effluent charges or emissions taxes. For example, several countries, including France and Sweden impose taxes on airborne emissions of sulfur dioxide, others including Germany and the Netherlands levy charges on effluents discharged into surface water.

Other kinds of activities also have environmental costs. In France, Switzerland, and Britain, airplane landings are charged through landing fees based on the amount of noise they generate. The scope for charges on environmentally damaging activities is clearly wide.

Product charges are levied not directly on the environmentally harmful activity itself, but on the product whose use is involved in that activity. Often, there is a close link between the use of a particular product and an environmentally damaging activity, but the sale of the product is considerably easier to monitor and tax. For example, although the discharge of CO_2 into the atmosphere is what creates the greenhouse effect, carbon taxes are levied on the carbon content of fuels that are burned to create carbon dioxide. For any fuel, average carbon content is constant, and no cost-effective large-scale methods of sequestering CO_2 after combustion are known, so the weight of carbon in the fuel and that of the carbon dioxide discharged are proportional. Moreover, imposing additional taxes on fossil fuels is far easier than monitoring and taxing CO_2 emissions directly.

Another example of a product charge is the U.S. tax on CFCs and certain other ozone-depleting halons identified in the Montreal Protocol of 1989. Since CFCs are chemically stable, virtually all CFCs used in production eventually escape to the atmosphere, contributing to ozone depletion. Of course, other product charges, such as taxes on petroleum feedstocks to finance the Superfund, are not directly connected to the environmentally damaging activity (in this case, improper disposal of hazardous wastes). The more tenuous the connection, the less effective are product charges in creating the right incentives. Sometimes, a trade-off must be made between the ease of administering a product charge and the accuracy in targeting the environmentally damaging activity that an effluent charge provides.

Related to product charges, but with significantly different revenue implications, are deposit-return charges—basically, product charges that are refunded when the product is returned to a designated collection point. Deposit-return charges are particularly appropriate when the policy objective is not only to discourage use of the product but also to encourage its proper disposal, including delivery to recycling facilities. The best known example of a deposit-return charge in the United States is that applied in many states to beverage containers under so-called "bottle bills." However, in other countries, similar charges are levied on tires, motor oil, lead-acid batteries, and vehicles.

Table 20. Illustrative Options for Environmental Charges, by Category

I. Effluent or Emissions Charges
1. on water effluents permitted under NPDES system
2. on toxic releases documented in Toxic Release Inventory
3. on vehicular emissions in Clean Air Non-attainment Areas
4. solid waste collection and disposal charges

II. Charges on Environmentally Damaging Activities
1. recreational user fees on public lands
2. highway congestion tolls
3. noise charges on airport landings
4. impact fees on installation of septic systems, underground storage tanks, construction projects with environmental impacts, etc.

III. Product Charges
1. taxes based on the carbon content of fossil fuels
2. gasoline taxes
3. excise taxes on ozone-depleting substances
4. taxes on agricultural chemicals
5. taxes on virgin materials

IV. Deposit-Return Charges
1. on vehicles
2. on lead-acid and nickel-cadmium batteries
3. on vehicle tires
4. on beverage containers
5. on lubricating oil

V. Reduction of Tax Benefits and Subsidies
1. percentage depletion allowances for energy and other minerals
2. percentage depletion allowances for groundwater extraction
3. charging market royalties for hardrock mining on public lands
4. eliminating below-cost timber sales
5. charging market rates for grazing rights on public lands
6. charging market rates for state and federal irrigation water
7. charging market rates for federal power

Although the product charge is ultimately refundable, deposit-refund systems nonetheless generate public revenues. Some deposits are never claimed, of course. Moreover, charges levied on products with long service lifetimes can allow a large interest-earning balance to build up in unrefunded deposits. If a charge is imposed on a product whose sales are growing, this balance also grows over time. Therefore, refundable product charges levied on durable goods with large markets and long service lifetimes—such as vehicles, batteries, tires, and consumer appliances containing CFCs—could generate substantial revenues.

Fees used to fund local, state, and federal government environmental programs are already used in forty-three states, generating a quarter of a billion dollars to fund environmental programs. (Shields, 1987) In most current applications, fees are structured primarily to raise revenues rather than to influence behavior. In other words, they are typically used as adjuncts to environmental regulations, and the rates reflect neither the marginal damages of the regulated activities nor the short-run costs regulated parties would incur in changing behavior. But even if they do not influence short-run behavior, as revenues sources fees are good alternatives to distorting taxes that impose heavy excess burdens on the economy. Moreover, in the long-run they are likely to discourage the environmentally damaging activity to which they are applied and encourage the search for substitutes.

Fees can be categorized as fees for service, discharge fees, impact fees, and user fees. (Doyle, 1991) Service fees help cover the costs of such environmental services as providing water or sewerage connections, or testing and monitoring water quality. Discharge fees are levied on the basis of actual or permitted discharges, such as vehicle emissions or hazardous wastes generated. Impact fees are imposed to reflect the environmental cost of an activity or the public costs of mitigating such impacts. Examples would include fees imposed on real estate developments impinging on wetlands or permit fees on the installation of septic systems. User fees are tied directly to the use of a public resource, such as water diversion fees or fees for grazing permits on public lands. *(See Table 20.)*

A. Effluent Charges

1. Charges on Releases of Toxic Substances Documented Under the Toxic Release Inventory

Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) required industries to report for public knowledge detailed information on the use, storage, and routine or accidental release of hazardous chemicals. It also required EPA to develop and maintain a public database on toxic emissions to air, land, surface waters, and underground sites. EPA's Toxic Release Inventory, published since 1987, now covers almost 24,000 reporting facilities that manufacture or process more than 25,000 pounds of any of more than 300 reportable chemicals. Although the inventory is based on self-reporting by regulated sources, the law provides for checks by regulatory agencies and penalties on sources for failure to report accurately.

Although the public availability of information about releases by manufacturing firms of toxic substances has prompted top management in many corporations to commit themselves to reduce emissions voluntarily (Smart, 1992), the 1990 inventory nonetheless documented total releases of toxic chemicals of 1.7 billion tons, exclusive of an additional 0.55 billion tons transferred to publicly owned treatment works (POTWs) and other offsite locations. Over 60 percent of all such emissions were atmospheric, and two-thirds of those were in smokestack gases. These emissions are subject to regulation under various environmental statutes—the Clean Water Act, the Clean Air Act, the Safe Drinking Water Act, and RCRA, for example—but the development of standards and implementing regulations has been slow and controversial, and the technology-based standards that have been generated are inefficient. (Portney, 1990)

Releases under the Toxic Release Inventory could be subject to environmental charges. Because the Inventory includes hundreds of chemicals released in many different ways into widely differing localities, basing charges on marginal damages would be impossible. Nonetheless, as an approximation, chemicals could be grouped into toxicity classes, based on EPA toxicity rankings, and charges could be graduated accordingly. For example, EPA has grouped chemicals into three overall "toxicity

potency groups" on the basis of their combined rankings in five toxicity indices that cover different aspects of potential risk. (USEPA, 1989) Charges could also be graduated according to medium of disposal—air, surface water, underground injection, surface impoundment, or transfer to POTW or offsite facility. Indeed, most POTWs and offsite disposal or treatment facilities already levy significant charges on transfers of toxic materials. Additional studies to estimate the relative damage levels of various categories of releases would help in establishing the appropriate gradations of such charges. Charges graduated in this way would provide incentives for polluters to find low-cost ways of abating toxic releases, particularly those that represent relatively high risks. Several studies have concluded that a substantial fraction of toxic releases could be eliminated at low cost. (US Congress, OTA, 1986) A tax base of 1.7 billion tons of toxic releases per year also creates a potentially large revenue base. For example, charges averaging just $20 per ton would yield $20 to $30 billion in annual revenues, depending on the incentive effect of the tax to stimulate additional emissions reductions. Charges set at this average level, with variations reflecting differences in toxicity and exposure potential, would not be likely to result in excessive emissions control since marginal damages are probably considerably higher.

Since charges based on reported TRI discharges would create an incentive for sources to underreport their releases, some of the revenues raised would have to be devoted to additional auditing and checking. The technologies available to monitor toxic releases in small concentrations in water, air and soils have advanced rapidly. To shift the burden of reporting accuracy to the firm, reported releases in a base year (or average of base years) prior to the imposition of charges could be used as a presumptive basis for the charge. However, regulated sources would be free to demonstrate reductions in releases beneath baseline levels through documented abatement measures and monitoring, and thus lower their tax liability.

2. *Vehicular Emissions Charges in Areas That Don't Meet Air Quality Standards*

Many urbanized regions, such as southern California and the northeastern seaboard, chronically violate national air quality standards, particularly for atmospheric ozone. In these regions, motor vehicle emissions of volatile organic compounds contribute significantly to the problem. Federal law requires these nonattainment areas to operate inspection and maintenance programs to control emissions from the vehicle fleet. In addition, new vehicles in certain areas must meet more stringent emissions standards.

Trying to control vehicular emissions through strict and increasingly expensive standards on new vehicles is relatively inefficient because the effectiveness of emissions controls deteriorates rapidly as vehicle use rises and improper maintenance takes its toll. Older vehicles with significantly higher emissions rates are responsible for large fractions of total miles travelled and total vehicular emissions. Moreover, evidence suggests that the added cost of stricter pollution-control equipment on new cars, by raising their prices relative to those of used cars, prolongs the life of older vehicles and raises the average age of the fleet. (Gruenspecht, 1982, pp. 328–331).

A charge on vehicular emissions in nonattainment areas could be implemented in conjunction with inspection and maintenance programs. Fees could be set on the basis of estimated annual emissions and collected when and where inspection stickers or vehicle registrations are issued. Charge levels could be roughly based on estimated marginal damages. For example, an EPA-sponsored study has estimated for the Northeast region that volatile organic compounds result in marginal damages of approximately $0.7 per kilogram. (Krupnick and Kopp, 1988) Other recent estimates range from $0.53 to $3.80. (Pace University, 1990) For a car emitting 1.5 grams of hydrocarbons per mile and driven for 10,000 miles per year, the

damage-based charge of $0.7 would come to about $10.00 per year. Such a fee would shift more of the burden of vehicular pollution control to owners of older cars in areas where vehicular emissions are especially troublesome, encouraging better maintenance or earlier retirement of highly polluting vehicles. In 1990, some 1.4 trillion vehicle miles were travelled in the United States, at least half in regions not attaining ambient ozone standards. Emissions charges averaging $10 per vehicle per year would generate approximately $0.5 billion dollars in annual revenues.

3. Effluent Charges on Surface Waters Discharges

The centerpiece of U.S. water pollution control legislation is a national permit system requiring industrial and municipal dischargers to meet technology-based standards that are uniform nationally within industrial categories. This approach, adopted in 1972 to ensure rapid clean-up action, has demonstrated most of the weaknesses of command-and-control regulatory approaches. It has taken more than a decade of deliberation and litigation to promulgate technology-based standards for all major industries, and the results are neither cost-effective nor efficient. The incremental costs per unit of clean-up may vary by more than an order of magnitude among plants in different industries sited side by side on a river. Uniform national standards are not strict enough to attain water quality goals in some surface water bodies, and much stricter than necessary in others. (Pederson, 1988, pp. 69–102) Even after regulated sources have installed required equipment, audits have found that significant fractions of sources are out of compliance for substantial periods of time because of equipment malfunction, in many cases without inducing any enforcement activities. (Russell, 1990)

Complementing these technology-based standards, the federal government has subsidized the construction of municipal and industrial wastewater treatment plants through grants and tax advantages. These subsidies have encouraged pollution sources to adopt end-of-pipe treatment technologies, even though pollution prevention and waste-reduction alternatives would have been more economical in many cases.[3] Although these efforts to control water pollution cost the nation more than $45 billion a year (Carlin, *et al.*, 1992), little actual improvement in water quality has resulted. (Freeman, 1990) Of water bodies for which monitoring reports are available, water quality in 36 percent of rivers, 54 percent of lakes, and 44 percent of estuaries is still too poor for swimming, fishing, or other intended uses. (USEPA, 1990)

Effluent charges can create continuing incentives for point sources to reduce discharges, particularly into surface waters that do not meet quality targets. Such charges are already used extensively in Germany, France, the Netherlands, and other countries. Such charges are based on formulas involving biological oxygen demand, chemical oxygen demand, suspended matter, nitrogen and phosphorus content, and other effluent characteristics. Although designed mainly to bring in revenues, charges in Germany and the Netherlands have also reduced industrial emissions. (Bressers, 1983)

Overall in the United States, more than 68,000 permitted sources discharge nearly 300 billion gallons of wastewater *daily* into surface waters. The Congressional Budget Office calculates that a charge based on biological oxygen demand at a rate equal to the mid-range of incremental abatement costs ($0.50 per pound) would raise about $2.4 billion per year. If such a charge superseded technology-based standards, transferring more of the total abatement burden to sources able to handle it more cheaply, overall water pollution compliance costs might drop by 25 to 30 percent—an annual savings of billions of dollars.

However, a nationally uniform effluent charge is only slightly more efficient than nationally uniform technology standards since some surface waters are now overprotected while others are underprotected. Moreover, effluents from

sources located along critical stretches of a water body have substantially greater impacts on water quality than effluents from sources located elsewhere. Effluent charges linked to local water conditions and administered by states in conjunction with effluent permits could be a valuable policy tool in improving U.S. water quality. If state governments designed and administered efficient charges, charges on heavily polluted rivers might be higher and charges on rivers already meeting water quality goals lower. California, New York, Indiana, Oklahoma, Washington, Colorado, Kentucky, and Arkansas already levy regulatory fees based on pollutant-discharge permits, mostly to raise revenues rather than to encourage abatement. Unfortunately, however, river basin authorities with fiscal authority to levy effluent charges and to finance treatment works, which can make even finer policy adjustments, are still uncommon in the United States, despite their success in Europe.

B. Activity Charges

Recreation Fees on the National Forests and Other Public Lands

Recreational uses of the nation's public lands may cause environmental damage, depending on the intensity and density of use. Off-road vehicles in the arid western regions can leave long-lasting scars on the land and harm fragile biota. Recreational boating can generate significant water pollution. Heavy traffic in some of the most popular national parks, such as Yosemite and Yellowstone, can have diverse environmental impacts ranging from vehicular air pollution to interference with wildlife habitat. Facilities built to accommodate downhill skiers and other recreational users are also sources of environmental disruption. To foster rational use of these valuable, sometimes unique, resources, user charges on these recreational activities should reflect the costs of environmental mitigation and damage.

User charges on recreational activities can provide public resource managers with more accurate information and stronger incentives to manage the public lands to achieve their maximum value in multiple uses. At present, the authority granted to such agencies as the Forest Service to charge recreational fees (except for the use of such facilities as campsites, lodges, and ski resorts) is severely limited by law. (Bowes and Krutilla, 1989, pp. 18-19) Consequently, revenues from recreation in the National Forests are small relative to those from timber sales, even though the aggregate value of recreational services provided by the national forests is much greater than that of the annual timber harvest. With approximately 250 million visitor days annually, at a conservative value of about $10 per day of recreational use, the national forests provide recreational services worth $2.5 billion per year, compared to the gross value of timber sales of $800 million in 1991.

The Forest Service gets most of its operating funds from receipts retained from timber sales under special provisions for reforestation, brush disposal, and road construction. Most of its appropriated funds are also linked primarily to timber management and harvest. In other words, in every national forest, even in those where timber production is uneconomic and other non-commodity services are more valuable, forest managers are overwhelmingly dependent on timber operations for funds. Neither funding source is linked to the profitability or net returns from timber harvests; rather, both are linked to the volume or gross value of sales. As a result, the paramount use of the national forests is timber production, even in regions where it consistently brings negative economic and financial returns. (O'Toole, 1990; Repetto, 1988)

If recreational and environmental benefits were reflected in Forest Service budgets as timber benefits are, then forest planning and management would serve those multiple use objectives more faithfully. To change bureaucratic incentives, individual national forest managers should be granted greater discretion in setting user fees to reflect consumer

demands and the incremental costs of providing services. They should also be empowered to set their own output plans for commodities and non-commodity uses. At the same time, individual national forests should become financially more dependent on *net* receipts from all sources and less dependent on Congressional appropriations.

Fee structures for natural forests could be differentiated by use. Campground fees could be retained as they are, but differentiated by forest and site to reflect the intensity of demand. Licenses to concessionaires and other commercial users could be revised to reflect fair market value. In addition, special permits could be sold for wilderness and "wild river" use. Other permit stamps could be sold for hunting and fishing in national forests, as some eastern state governments now do through cooperative agreements with the Forest Service. In addition, a general annual entry fee in the form of an easily monitored bumper sticker could be sold at a modest price, allowing unlimited recreational uses not covered by any other permit or license. (O'Toole, 1992, pp. 18–21) The Forest Service estimates that if it collected the full value of the recreational services it provides, annual revenues would reach $5 billion. Even if fees totalled half that amount, they would dominate timber revenues in most of the national forests, creating strong incentives for the Forest Service to accord higher priority to recreational and environmental considerations in forest management. At the same time, fees would sensitize consumers to the value of the services the forests provide.

C. Product Charges

1. Additional Stratospheric Ozone-Depleting Substances

The U.S. committed itself under the 1987 Montreal Protocol to halve consumption of the most ozone-depleting CFCs and halons by 2000. In 1990, on the basis of new information about the pace of stratospheric ozone loss, the U.S. and other signatories agreed to a faster schedule, completely ceasing use of controlled substances by 2000, and added ten additional CFCs and two other compounds, methyl chloroform and carbon tetrachloride, to the list of substances to be rapidly phased out. In addition, the London Revisions identified other halons as chemicals of concern and specified a list of hydrochlorofluorocarbons (HCFCs) being developed as CFC substitutes with lower ozone-depleting potential as "transitional substances" to be used with discretion. The 1990 Clean Air Act amendments committed the United States to a HCFC phase-out by 2030. In 1992, the United States announced a further schedule acceleration pegged to a phase-out target of 1996.

To encourage users to seek out substitutes and to forestall windfall producer profits as output declines, Congress in 1989 enacted an excise tax on these compounds. The rate on each compound, reflects its ozone-depleting potential over its atmospheric lifetime relative to CFC-11, and is scheduled to rise over time. Exemptions and reductions apply to the quantities of these compounds used in rigid foam insulation as chemical feedstocks, recycled or exported. Tax rates were revised and the coverage of the tax was extended in 1990, and tax rates were again raised in 1992. Although U.S. production of CFCs has declined rapidly in recent years, and it is already 40 percent below ceilings under international agreements, these taxes generated revenues exceeding $500 million in 1991.

However, other ozone-depleting substances, principally halons (compounds containing bromine) and HCFCs, are currently not taxed. Since the atmospheric lifetimes and ozone-depleting potentials of these substances are typically less than those of CFCs, and HCFCs in particular can substitute adequately for CFCs in many uses, they have been regarded as an environmentally preferable interim replacement for banned compounds. Already, substitutes have replaced 10 to 25 percent of CFC

consumption, despite their four or five-fold higher prices; their use has risen by 8 to 9 percent per year since the mid-1980s and is expected to continue to rise throughout this decade. As a consequence, HCFCs and other halons have come under increasing scrutiny. Industries have attempted to ensure that investments in increased capacity in these CFC substitutes would not be undermined by regulatory bans, and environmentalists have sought to extend regulatory control over them. The Clean Air Act amendments of 1990 required a phase-out of HCFCs by 2030, banned certain applications, and mandated recycling.

The excise tax on ozone-depleting substances could usefully be extended to HCFCs and other ozone-depleting substances. Tax rates could be based on the same scale of ozone depletion potential now applied to CFCs and other taxed compounds. This would be a better approach than banning them at a specified future date. Extending the tax to these compounds, with rising rates over time, would spur further innovation, encourage substitutions, and would discourage increases in consumption. In particular, a tax would discriminate between essential and irreplaceable uses on the one hand and those for which relatively inexpensive alternatives can be developed and adopted on the other. Projected U.S. uses of HCFCs for 1997 total approximately 500 million pounds. Applying tax rates applicable in that year and an average ozone-depleting potential of 0.05 yields annual potential U.S. tax revenues of roughly $300 million.

Particularly relevant would be extending the tax to methyl bromide, a biocide used mainly as an agricultural soil fumigant in the production of such high-valued crops as strawberries and ornamental plants. Worldwide production and sales of methyl bromide rose from 42,000 to 63,000 tons between 1984 and 1990. (UNEP, 1992) U.S. sales in 1990 totalled approximately 62,000,000 pounds. In the short run, methyl bromide is 30 to 120 times as potent per atom as chlorine compounds, but because its atmospheric lifetime is only about 1.5 years, its total ozone-depleting potential is only 60 percent that of CFC-11. Despite its small atmospheric concentration, reducing methyl bromide emissions would reduce ozone depletion significantly over the short term. In terms of reducing peak ozone depletion, expected to be at its worst in the 1990s, each 10-percent reduction in methyl bromide atmospheric concentrations would be equivalent to a three-year advancement of the current phase-out date. (UNEP, 1991)

A tax approach is particularly suitable for reducing methyl bromide use because some uses have ready substitutes and others do not. In most agricultural uses, for example, crop rotation, the use of other soil fumigants, and the acceptance of higher crop losses are all possible alternatives. However, in some agricultural uses and in quarantine treatments, acceptable substitutes are unavailable and users would incur heavy losses if methyl bromide consumption were curtailed. Therefore, bans would either impose hardships on some users, or require complicated discriminatory treatment of different users. A tax, however, would allow users highly dependent on methyl bromide continued access to it, with strong incentives to seek substitutes. At the same time, it would induce users with access to satisfactory alternatives to methyl bromide to stop using it. At 1993 tax rates of $2.75 per pound, a tax on methyl bromide would raise approximately $60 to $90 million per year in revenues, depending on the elasticity of demand. Moreover, since the tax would raise the price of methyl bromide substantially, it would provide strong market incentives to accelerate methyl bromide's replacement with more benign substitutes.

2. *Agricultural Chemical Taxes*

Serious ecological and health risks stem from the use of fertilizers and pesticides in the United States. Since only a minor fraction of the chemicals applied actually reach their intended target, applications create a

potentially large externality. In fact, agricultural fertilizers constitute the largest non-point nutrient source of eutrophication of the nation's surface waters. Nitrates leaching into drinking water supplies from agricultural fertilizer applications are recognized as a substantial health risk in some regions. According to a recent EPA survey, 2.4 percent of rural domestic wells contain nitrates at concentrations exceeding EPA's health advisory level. (EPA, Office of Pesticides and Toxic Substances, *National Pesticide Survey: Nitrate,* Washington, D.C., 1990)

Pesticides as a group are rated high on the scale of environmental risks, though the 50,000 registered herbicides, fungicides, and insecticides on the market vary widely in toxicity, persistence, ability to bioaccumulate, or to travel through the environment. Next to the risks to global environment, for example, EPA's Science Advisory Board ranked pesticide exposure among the most serious domestic ecological and health risks. (USEPA, 1990b) This confirmed the findings of an earlier EPA effort to prioritize environmental risks; in it, pesticide exposure was characterized as one of the most serious risks with respect to cancer, other health effects, and ecological damages. (USEPA, 1987)

EPA's regulatory efforts to control non-point source pollution, described in Section 319 of the Clean Water Act, emphasize assessments and state-level management programs, but have had limited impact. Provisions in the 1990 Farm Bill extend the priorities of USDA's Conservation Reserve Program to take land out of production to improve water quality, to establish a Wetland Reserve Program, and to offer cost-sharing grants and technical assistance to farmers developing and implementing farm-level water-quality plans. But these provisions scarcely counteract the strong economic incentives in the Farm Bill that induce farmers to retain chemical-dependent farming systems and to push yields above a market equilibrium level. (Faeth, 1991)

Pesticide regulation under FIFRA has been one of the most difficult and unsatisfactory of EPA's programs, largely because EPA was charged with the almost impossible task of regulating more than 50,000 products based on over 600 active ingredients. EPA is supposed to compare each chemical's risks and benefits in each of its uses in each distinct agroecological region. (Dorfman, 1982) Every risk assessment involves lengthy, expensive laboratory tests leading in the end to extrapolations of toxicity from rats exposed at very high doses to humansexposed at very low doses. The health risks reduced by eliminating any pesticide from use depend on what other pesticide is adopted in its place, making it imperative that assessments consider relative risks for groups of (chemically quite different) products with similar uses. Estimating the agricultural benefits of using any pesticide is complicated by complex ecological responses in the field, such as the emergence of pesticide resistance and pesticides' tendency to stimulate secondary pest outbreaks. (National Coalition Against the Misuse of Pesticides, 1992) Regulatory analysis is carried on through complex administrative procedures safeguarding the rights of all parties, and subject to legal challenge at virtually any point. In view of all these difficulties, it is not surprising that EPA manages to register only 10 to 15 new active ingredients per year, and since 1988 has completed reregistration proceedings for only 14 of the active 614 ingredients already in use. Even when regulations are completed, unless a chemical is totally banned from all significant agricultural uses it is difficult for regulatory agencies to ensure that farm operators follow label instructions and restrictions.

Environmental charges could strengthen pesticide regulations and water quality programs for non-point sources. An environmental charge on pesticides should be set at several different rates to reflect the relative risks presented by different compounds. Risk categories can be constructed from existing rankings based on acute toxicity to humans, chronic or long-term health risks, toxicity to

other non-target species, persistence, solubility, soil absorption, and other relevant characteristics. Imposing higher charges on pesticides entailing higher risks would encourage both producers and users to find and adopt safer substitutes. Of course, EPA should continue to ban pesticides that pose unacceptable risk levels. But since the pace of this process is so slow, a supplementary charge system would help reduce risks in the short run and stimulate the evolution and adoption of safer means of pest control over time.

A fertilizer tax would give farmers an incentive to use less fertilizer, offsetting incentives built into commodity programs and other agricultural supports that push them to use more. Such a tax would extend the "polluter pays" principle to agriculture, creating a stick to supplement the carrots offered to farmers to participate in non-point source pollution-control programs. Studies suggest that the elasticity of response to a fertilizer tax would be significant in any case, partly because many farmers are overusing chemical fertilizers, with little or no incremental boost to production. If commodity support programs allowed farmers more flexibility in planting and production decisions, it would be greater still. (Hrubovcak, et al., 1990, pp. 208–212)

Several states, including California and Iowa, impose fees on fertilizers and pesticides, though the rates per ton are quite low. Various countries, including Denmark, Sweden, and Austria, also employ such charges. According to estimates by the Congressional Budget Office, a tax on chemical pesticides and fertilizers at rates averaging 10 percent *ad valorem* would generate revenues of nearly $1 billion per year. Current expenditures on pesticides, of which two-thirds is for agricultural use for example, are approximately $8 billion per year. Most farm expenditures on pesticides are for herbicides for use mostly on crops subject to commodity support programs, such as corn, wheat and soybeans.

D. Reducing Environmentally Damaging Subsidies and Tax Advantages

1. Eliminating the Excess of Percentage Over Cost Depreciation for Mineral Extraction Activities

Current law allows independent oil and gas producers, hardrock mining companies, and some other enterprises that extract non-renewable resources to deduct certain percentages of gross revenues from taxable income as depletion allowances. Over time, these depletion allowances may exceed the cost of the enterprises' investments in the development and extraction of the resource—a write-off that investors in other industries never get. The excess of percentage depletion over cost depletion constitutes a large subsidy to the extractive industries, raising returns to investors and increasing production.

These subsidies have damaging environmental impacts. First, they stimulate mining and other extractive activities that have heavy local and regional environmental impacts. Second, they stimulate the production of such toxic materials as asbestos, lead, mercury, cadmium, and uranium—all of which qualify for the highest depletion allowance of 22 percent. Third, since they subsidize the production of virgin materials, they depress secondary materials markets for iron, aluminum, and other metals, thus working against recycling programs. Finally, by subsidizing production of fossil fuels, they discourage energy conservation and the development of renewable energy sources.

According to the Office of Management and Budget, annual revenue losses from the excess of percentage depletion over cost depreciation in the fuels and non-fuels minerals industry total well over $1 billion per year. (US Office of Management and Budget, 1992, Ch. 24)

Eliminating this advantage for all remaining beneficiaries in the oil and gas industry would generate additional revenues of $795 million in 1993. A similar reform in other mining industries would produce $365 million.

2. *Charging Market Value for Commodities Produced on Public Lands*

a. Minerals

Hardrock mining on public lands remains subject to the Mining Law of 1872, which allows claimants to obtain rights to mineral exploitation—without payment of royalties—at a nominal cost of $2.50 to $5.00 per acre. Patenting of land rights under this law also allows private parties to obtain land at a small fraction of its market value. This federal largesse toward the mining industry contrasts sharply with the government's treatment of its petroleum and gas resources, which are leased to private developers on the basis of competitive bids and which generate substantial royalties and other revenue payments.

Like percentage depletion, this giveaway of public mineral resources generates direct and indirect environmental damages, while depriving the Treasury of considerable revenues. In recent testimony, a former senior government budget official estimated the potential revenue gain from pricing federal mineral resources appropriately to be in the vicinity of $0.6 billion per year. (Rivlin, 1989)

b. Water

Irrigation water supplied by Bureau of Reclamation projects is heavily subsidized. The intent of initial legislation was that recipients would repay the costs of constructing, operating, and maintaining the massive storage and conveyance works over time into a revolving fund. However, fifty-year, interest-free loans with ten-year grace periods and amortization at historical costs, together with creative accounting that continually defers the repayment period and allocates much of the costs of multipurpose projects to flood control and power generation, have made a mockery of this intention. The average subsidy on 140 of the Bureau's operating projects is estimated to be 83 percent of full project costs, and the subsidy on projects under construction is likely to range from 92 to 98 percent. (Repetto, 1986, pp. 15-16) The value of this subsidy exceeds $1 billion per year—over $35 per acre-foot of water. Worse, it goes to fewer than 6 percent of American farmers, and of these, the largest 5 percent garner over half the total benefits. Moreover, this subsidy of storage and delivery costs is just the tip of the iceberg. The water itself, for which favored farmers pay essentially nothing, is worth hundreds of dollars per acre foot in alternative municipal and industrial uses.

These subsidies have encouraged low-valued and inefficient applications of water. Indeed, almost half of the water supplied is used to irrigate hay, alfalfa, sorghum, corn, and other relatively low-valued crops. Conveyance losses through unlined dirt irrigation canals and ditches are high, even while municipal, industrial, and recreational water users are hard-pressed to find adequate water supplies. Eliminating even this wastage would provide enough additional water to meet all municipal needs in the West through the end of the century. (Moore and Willey, 1991, pp. 775-825)

Severe environmental damages accompany this economic waste. The production of large areas of farmland within Bureau of Reclamation project areas has been impaired by salinization. Mineral-laden drainage waters have poisoned wetlands and destroyed wildlife. Excessive diversions and storage have brought about extensive ecological changes that threaten the survival of several species.

The western states are moving to encourage water transfers from subsidized irrigators to municipal users whose alternative costs for new water sources are typically an order of magnitude higher than the marginal value of

water to farmers. Such transfer will reallocate water to higher-valued uses, while allowing farmers to cash out the value of their subsidies. Renegotiating Bureau of Reclamation contracts to recover the full capital and operating supply costs of water would encourage such transfers, while stimulating more efficient water use within agriculture. At the same time, it would add approximately $500 million per year to federal revenues.

c. Timber

Most of the Forest Service domain is unsuitable for commercial timber harvest. The National Forest Management Act of 1976 instructed that areas unsuitable for timber production for economic or physical reasons be removed from the timber base, but timber operations, driven by national production targets and pressures from local lumbering interests, have actually increased in many forests where they consistently generate less in revenues than the cost to government of growing and selling the timber. Many of the forest regions where timber sales chronically fail to recover these costs contain thin stands of relatively low-valued timber, have slow rates of regeneration and growth, and require expensive road construction on difficult terrain. Despite obscure Forest Service accounting practices, analysts inside and outside government have agreed that below-cost timber sales are prevalent throughout the Rocky Mountain states, in Alaska, and in the East. (Repetto, 1988)

The Forest Service has repeatedly justified its below-cost timber sales by claiming that they generate non-timber benefits—among them, easier recreational access, improved wildlife habitat, and increased water supplies. However, the supposed beneficiaries, including state Fish and Game Agencies and associations of naturalists and outdoor recreational users, vehemently oppose Forest Service claims and logging plans. They cite destruction of wildlife habitat, the loss of water quality through soil erosion, the elimination of prized roadless forest areas, and other adverse environmental impacts.

Requiring that the Forest Service establish a minimum bid for all timber sales that would recover the full costs of growing and selling the trees, and requiring the Forest Service to implement the National Forest Management Act provisions to eliminate uneconomical forest regions from the timber base, would do much to eliminate these timber subsidies. A more fundamental reform would also amend the laws that currently set aside percentages of *gross* timber sales revenue for payments to local governments and use within the Forest Service and would instead base such allocations on *net* receipts, including receipts from recreational fees. This new approach is applicable to grazing and mining revenues as well as to timber receipts, and to the Bureau of Land Management as well as the Forest Service.

The subsidy implicit in below-cost timber sales has fluctuated with the volume of sales and market prices for logs. It has recently been estimated at approximately $0.4 billion per year. (Rivlin, 1989) Charging market prices for all commodities produced from the public domain would thus bring the federal Treasury an additional $1.5 billion per year, while curtailing substantial ongoing damages to the nation's environment.

E. Conclusion

These wide-ranging examples demonstrate the ample opportunities for applying environmental charges and reducing environmentally damaging subsidies. The options discussed here might generate nearly $40 billion in new revenues and could have been augmented by many more examples, as Table 20 suggests. Seizing such opportunities will allow federal and state governments to raise revenues in ways that improve economic productivity while strengthening environmental protection. At the margin, these revenue options are far more attractive than conventional taxes on payrolls, incomes, profits, and savings that destroy

badly needed economic incentives and reduce the competitiveness of the U.S. economy. Shifting as much as 10 to 15 percent of the total federal, state, and local revenue base toward environmental charges—such as those described here—would help keep America's economy and environment healthy and strong.

Notes for Chapter 5

1. For a more complete inventory, *see* US Congress, Joint Committee on Taxation (1990).
2. For a more recent survey of environmental charges in other OECD countries, *see* OECD (1989).
3. To qualify for accelerated (5 year) depreciation for tax purposes, a pollution control facility must not significantly increase the output capacity or useful life of the plant, nor may it reduce operating costs nor pay for itself through waste recovery! Richard A. Westin and Sanford E. Gaines (1989, p. 768)

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