OPTIMAL ENVIRONMENTAL TAXATION

by
William K. Jaeger

Waite Library
Dept. of Applied Economics
University of Minnesota
1994 Buford Ave - 232 ClaOff
St. Paul MN 55108-6040 USA
Note: This paper is intended for private circulation and should not be quoted or referred to in publication without the permission of the author.
Optimal Environmental Taxation

William K. Jaeger
Department of Economics, Williams College
Williamstown, MA 01267

Revised February 1997

ABSTRACT. Congestible natural assets that are prone to market failure include pastures, fisheries, and aquifers, but also the assimilative capacities of waste sinks such as rivers, oceans, air and atmospheres to absorb and eliminate the residual by-products from consumption and production. Each of these assets corresponds to goods and services that should be priced at marginal cost in a first-best world (for example using Pigouvian taxes where property rights cannot be assigned). In a second-best world where government also uses taxes to raise revenue, each of these separate goods should also be taxed additionally as part of an optimal revenue-raising tax program with “Ramsey” taxes.

In each case, the taxes on these exogenously-supplied congestible assets will produce two benefits: it will restore allocative efficiency, and (up to the Pigouvian price) it will appropriate the resource rents as a non-distorting source of revenue. The “total” optimal tax will in general be higher, and the optimal pollution level lower, because Ramsey taxes are added to to Pigouvian pricing of the good. The two welfare benefits from these taxes will derive from improved allocative efficiency and tax efficiency.

Based on a general equilibrium model with k commodities and n-k environmental waste sinks, the analysis further shows that even if pollution damages are zero, it will still be optimal to tax waste disposal because it broadens the tax base and pays to concentrate distortionary taxes on exogenously supplied resources. In this case, Pigouvian pricing (equal to zero) combined with indirect labor taxation will not produce efficiency because it would capture no rents from the free waste disposal service.

These conclusions support the strong double dividend hypothesis, and are more general than those in recent literature which has called into question the strong “double dividend” hypothesis. This is due primarily to the inclusion of waste disposal services separately in the model, and by allowing non-zero marginal rates of technical substitution between commodities and disposal.
I. Introduction

The principles of optimal commodity taxation are among the oldest in the public finance literature dating back to Ramsey (1927), and the theory of optimal corrective taxation of externalities is also well-established and dates to Pigou (1947). Nevertheless, these two strands of theory have never been adequately integrated, as evidenced by recent debate, awkward intuition, and conflicting conclusions about optimal taxation when pollution taxes interact with the existing revenue system (for example, see Oates 1993, 1995; Terkla 1984; Lee and Misiolek 1986; Bovenberg and de Mooij 1994, Bovenberg and Goulder 1996).

To provide both a consistent framework for combining these two strands of theory and shed light on the recent controversy, this paper integrates corrective environmental taxation and optimal tax theory in a general equilibrium model where the environmental resources themselves, rather than the metaphorical “externalities” that may arise from their use, are the focus of attention. We take as our starting point that natural environments such as the air, rivers, lakes, oceans, atmosphere, and subsoil systems represent public goods (or assets) that provide services and produce commodities. In particular, we emphasize the capacity of these “waste sinks” to absorb, store, or assimilate the residual by-products from production and consumption. These environmental assets also provide other services, such as clean air and water that protect human health, increased productivity of land or other resources, recreational amenities, and production of commodities such as fish (Mäler 1985).

The assimilative capacity for waste disposal, however, is a congestible public good characterized by capacity constraints. Thus, pollution problems can be seen as market failures that arise when property rights to the assimilative capacity of natural environments are neither assigned nor enforced. Unrestrained use of the assimilative capacity of natural environments, and their stock effects on amenity and other benefits, constitute an
inefficient allocation of the exogenously supplied resource, and lead to the dissipation of potential resource rents.

Pollution problems have traditionally been referred to by economists as "externalities." However, as will be shown below, the metaphorical notion of an externality draws attention away from the environmental resource in question—the waste sink itself and its assimilative capacity—and instead bypasses the waste sink and characterizes economic systems as having direct, abstract and inflexible links between the consumption of particular commodities and some unavoidable negative effect on a particular environmental amenity. By explicitly modeling the environmental assets and their services, the analysis below offers a more legitimate basis for integrating "first-best" corrective environmental tax theory with "second-best" optimal taxation when distortionary taxes are needed to raise revenue.

As will be shown, the results of the exercise are straightforward. The assimilative capacities of natural environments represent services from exogenously provided assets. They should be taxed directly as part of a broadly based tax program. But like exhaustible resources, the rents from these resources can be taxed without producing distortionary effects. In the case of waste sinks we can see that, up to the Pigouvian tax rate, there are two benefits from taxing waste disposal; the restoration of allocative efficiency and the appropriation of rents for a previously free but economically valuable asset. The combination of these two effects produces two benefits or a "double dividend" when environmental taxes on waste disposal is introduced in a revenue-neutral way. By substituting nondistortionary taxes (or "less" distortionary taxes above the Pigouvian tax rate) on resource rents for other distortionary taxes, the excess burden of the tax system is lowered.

Intuitively, when environmental services are used at efficient levels, the Pigouvian price simply represents the unit cost of the waste disposal service, and thus is the appropriate base price to which second-best revenue raising taxes should be applied.
Therefore, in general, the second-best optimal tax applied directly to environmental waste sink services will be higher, and the optimal level of pollution will be lower, than those implied by the standard Pigouvian analysis.

The rationale and intuition of the model is developed in more detail in section II. Section III presents the basic theoretical results in a simple three-good model. The analysis is expanded in Section IV to include an n-dimensional general equilibrium model with some interpretation and implications of the results. Section V discusses the existing literature on externalities and the double dividend. Section VI concludes.

II. Basis for conceptual model

It has long been recognized that the problem of environmental pollution stems from the unavoidable generation of residual byproducts inherent in virtually all production and consumption activities. The possibility of disposing of these residuals in a convenient environmental sink such as air, atmosphere, watercourse, or landfill, represents an important economic service to consumers and producers (Mäler 1985). Were such services unavailable, residual disposal would inevitably be more costly since individuals would be forced to dispose of waste in less convenient ways or ultimately to accumulate and store stocks of these residuals.

It is also important to recognize the considerable degree of substitutability and flexibility that exists between and among waste sinks and between other goods and waste sinks. Residuals may be recycled or discharged directly into environmental media with or without modification (Kneese 1971); although most residuals can be transformed into forms that make it possible to dispose of them in numerous alternative media. For example, through the application of equipment and energy, most substances can be removed from water or air streams and transformed into residuals that can be disposed of in solid form or reused (Kneese 1971). And residuals may be transported and disposed of
in distant environmental sinks where pollution costs may be lower due to higher assimilative capacity, lower current flows, or their remoteness from human activity.

By contrast, externality models assume away such substitutability, and ignore the natural resource altogether.

Natural environments often provide several kinds of services in addition to waste assimilation, such as clean air and water that protect human health, amenity benefits consumed directly, by enhancing the productivity of other assets (i.e., land, forests), and commodities such as fish and game. They represent neither "pure" public or non-rival goods nor strictly rival goods, but rather may be characterized as "congestible public goods" which, like highways, beaches, aquifers, pastures, or fisheries, can become congested beyond some level of use.

In the case of the assimilative capacity for waste, the congestability of these sinks means that above some threshold level of residual flows there will be a stock effect which can cause deterioration of the environment’s other services (e.g., unhealthy air, unswimmable water, loss of protection from solar radiation, loss of output in forestry, fisheries, or agriculture). The conflict arises not between competing users of the environment as a waste sink, nor among competing users of the amenities associated with the natural environment, but rather between those who derive utility from using the environment as a waste sink and those who derive utility from its other services (e.g., protection of human health, amenities) at levels available in its uncongested state. These congestion costs are asymmetric: the level of waste flows may reduce amenity benefits, but increased demand for amenity services does not affect the sink's assimilative capacity.

Pollution problems, therefore, are best understood as market failures that occur when the property rights associated with use of a natural environment—either for its amenity benefits or assimilative capacity—are neither assigned nor enforced. Without such property rights the services of these exogenously supplied environmental resources will be misallocated and their rents will be dissipated.
A. Externalities

Although the preceding characterization of environmental resources and their role in an economy differs considerably from the more familiar notion of an “externality,” the conceptual basis and precise definition of an externality has long been elusive. The literature contains numerous definitions and classes of "externalities" (Bator 1958; Buchanan and Stubblebine 1962; Coase 1960; Meade 1952), but there is no straightforward, intuitive, or standard definition. Indeed, Baumol and Oates (1988) observe that for a definition of an externality "one is left with the feeling that we still have not captured all its ramifications" (p. 14). They point out that in several seminal works on the subject, externalities are not defined formally or are defined not in terms of what they are, but what they do (Baumol and Oates 1988, p. 16). Others have suggested that the notion of an externality is not a useful term at all (Cheung 1970), or even that it is "a vacuous and entirely unhelpful term, and [should] be replaced by the more general term inefficiency with no loss of content" (Randall 1983, p. 132).1

In a more appealing and useful interpretation, however, Arrow (1969, cited in Baumol and Oates 1988, p 16) recognized the need to associate externalities “with the absence of some markets for the trading of items affecting the welfare of economic agents.” Unfortunately, however, by defining an environmental problem as one involving externalities, which in effect defines away the item, has had the effect of drawing economists’ attention away from the resource that is at the heart of the allocation problem being addressed, and instead to think of an externality as a vague and almost imaginary link between the consumption of a particular “dirty” commodity (or input into production) and a negative effect on other economic agents, thus bypassing completely the

1 In some cases the poor fit between the metaphor and the resource has led to even more strained attempts to generalize the theory by defining and distinguishing between "depletable externalities" and "undepletable externalities" (Baumol and Oates, 1988) rather than by recognizing the difference between environments for which use is excludable and non-excludable.
environmental resource itself, its assimilative capacity, or the degree of substitutability between and among environmental waste sinks.

B. Waste disposal and utility

For the analysis here, recognizing the role of waste disposal in utility is essential. When residual wastes are generated and the alternatives to environmental waste disposal are limited or higher cost (such as storing the waste indefinitely) these environmental services contribute to well-being. The household production function approach to utility, whereby the “commodities” that provide utility directly are produced within the household by combining purchased market goods, other services and some of the household's own time (Lancaster, 1971; Michael and Becker, 1973), is recognized to be advantageous for environmental economics applications (Mäler 1985, p. 15). The need to explicitly model the household production function directly is avoided because one can substitute it into the utility function to get the derived utility function in terms of goods, time, and environmental variables (Michael and Becker 1973).

In addition to the range of alternatives for waste disposal noted at the beginning of this section, the household production function approach recognizes still additional substitution possibilities involving consumer choices provided for within the household production function. For example, individuals may derive utility directly from maintaining bodily warmth. Indirectly, the inputs into the household production function that produce bodily warmth may include various combinations of fossil fuels, local atmospheric disposal of residuals, electricity, warm clothing, and home insulation. And while fossil fuels and waste disposal services are strong complements to be sure, a wide range of substitution possibilities may exist between alternative sources of energy (natural gas, electricity, solar), alternative waste sinks (local versus more distant ones), as well as substitution of home insulation, wool sweaters, etc.. Even if the marginal rate of technical substitution between consumption of a particular energy source and the quantity of residuals produced
is zero, the substitutability at the level of the derived utility function will be greater than zero in the presence of alternative waste sinks, recycling possibilities, indefinite storage, or the application of technologies that reduce, modify, or transform the residuals.

By contrast, the externality approach to defining environmental pollution has been problematic in this context because it has led economic modelers to ignore the utility derived directly from environmental waste disposal. This kind of omission is not new. Indeed, there is precedent within the public finance literature for erroneous conclusions being drawn when omitting goods from the utility function. For example, traditional models of optimal taxation held that unequal taxation across different goods could raise revenue with a zero welfare cost. Not until Little (1951) and others pointed out that leisure should be introduced as a separate good, was it recognized that this result did not hold. The current analysis suggests that a similar problem exists with regard to environmental taxation. By failing to recognize that environmental waste sinks are separate goods, and by omitting environmental waste disposal services from the utility function, optimal tax theory has overlooked the rationale for pricing and taxing them directly, and separately, from the taxes on other goods and services in the economy.

C. A thought experiment

With the recognition that environmental services constitute goods that should be represented separately in the utility function as well as in taxation, and allowing for flexibility in the amount, form, and location of waste disposal, the implications for optimal taxation are straightforward. The validity of the double dividend argument can be understood with the help of a thought experiment.

Consider the welfare implications in a second-best world--where raising revenues is costly--under two alternative policies that would create secure property rights to waste sink disposal in the form of tradable emissions permits. First, assume that the efficient level of pollution is attained with the free distribution of the optimal number of permits (x*
in figure 1). Assuming a competitive market in permits, this will achieve allocative
efficiency and produce the full social benefits normally expected with a Pigouvian tax since
the permit price will be expected to equal the Pigouvian price $p^*$. 

Now, assume a similar intervention except in this case the permits are auctioned
off and the revenues, $x^*p^*$, are used to finance marginal reductions in existing tax rates on
other goods and services. This will also restore allocative efficiency and produce the
social benefits expected with a Pigouvian tax since the auction price will be equivalent to a
Pigouvian price. However, in this case there is a second benefit resulting from the
recycling of tax revenues into the tax system for two reasons. First, because the tax base
has been broadened to include waste disposal, and second, because the rents from waste
disposal have been appropriated by government. Since raising revenue is distortionary,
the transfer of rents, $x^*p^*$, from an individual to the tax authority will produce a net social
benefit so long as the marginal cost of raising a dollar of revenue in the tax system is
higher than the marginal utility of income—a result that is well-known for taxation of
exhaustible resources rents. Since there is zero distortionary effect of the pollution tax up
to the Pigouvian price, $P^*$, it follows that the “fully-optimal” tax on waste disposal will
likely be higher than the Pigouvian price.

III. Optimal environmental taxation in a three-good model

The proposition that separate taxes on environmental waste disposal (and not just
on “dirty goods”) should be part of an optimal tax program can be demonstrated more
formally with a simple three-good model where good $x_1$ is a (composite) consumer good,
good $x_2$ is a (composite) environmental waste sink service, and good $x_3$ is leisure. We
want to represent the welfare cost if we allow only goods 1 and 2 to be taxed in order to
raise a given amount of revenue $R$. Following some well-known derivations (Corlett and
Hague 1953-54; Harberger, 1964), we define quantities of the goods such that their unit
costs are unity. For a given set of unit taxes $t_1, t_2, t_3$, we can write, following Harberger (1964), the welfare cost of taxation as

$$W = -(1/2) [S_{11}t_1^2 + S_{22}t_2^2 + S_{33}t_3^2 + 2S_{12}t_1t_2 + 2S_{13}t_1t_3 + 2S_{23}t_2t_3].$$

And in the case where leisure is the untaxed good

$$W = -(1/2) [S_{11}t_1^2 + S_{22}t_2^2 + 2S_{12}t_1t_2].$$

Our interest here is in comparing the welfare cost of taxation with and without a tax on waste disposal, $x_2$. If environmental waste disposal is initially free ($p_2 = 0$) then neither allocative efficiency nor tax efficiency will be achieved. Assume, however, that following Pigou's well-known first-best result, efficiency will be achieved when $p_2 = p_2^*$ at the point where demand for waste disposal equals the marginal congestion cost. This correction could be achieved by a Pigouvian tax, but let's assume for the sake of this exposition that the property rights failure is corrected by issuing $x_2$ emissions permits to a private agent who then sells all the permits in a competitive market. The market price should equal the Pigouvian price $p_2^*$ for the fixed quantity of permits $x_2^*$. This correction will, of course, raise welfare by restoring efficient use of the waste sink. But should waste disposal also be taxed to raise revenue? In a second-best world when raising revenue is costly, all goods and services should be taxed to broaden the tax base (with few exceptions as described below), and in this case that means “taxing the tax” since the corrective tax simply restores allocative efficiency, and then the distortionary tax should be added on to that corrective tax so that the full tax on waste disposal will be above the Pigouvian level.

To answer this formally, we assess first the situation with an excise tax $t_1$ on $x_1$ alone. The welfare cost in this case is simply

$$W_1 = -(1/2) S_{11}t_1^2.$$  

Now we want to assess the impact of including a tax on $x_2$. To raise revenue $R$, an income tax $t^*$ will be an implicit tax on consumption of $x_1$ and $x_2$, and have equal yield to $t_1$ above

---

2 The Harberger formulas are approximations based on the assumption that demand curves are linear over the relevant range, and by assuming utility is held constant through compensation.
when \( t^*(x_1 + x_2) = t_1 x_1 \), or where \( t^* = t_1 x_1 / (x_1 + x_2) \). In this case the welfare cost for this income tax becomes \( W_2 = -(1/2) S_{33}(t^*)^2 \). Following Harberger (1964, p. 50), we can write

\[
W_1 - W_2 = -(1/2)[S_{11} t_1^2 - S_{33}(t^*)^2],
\]

or

\[
W_1 - W_2 = -\frac{1}{2} S_{11} t_1^2 \left[ 1 - \frac{S_{33}}{S_{11}} \left( \frac{t^*}{t_1} \right)^2 \right]
\]

to express the difference in welfare cost between a revenue raising tax program which taxes \( x_1 \) only \((W_1)\), or one that implicitly taxes both \( x_1 \) and \( x_2 \) \((W_2)\), when \( x_2^* \) is sold by a private agent at the Pigouvian price. We wish to know which equal yield tax program has the lowest welfare cost. The difference between the two welfare costs can be seen to be equal to the "correction factor" \( [S_{33}/S_{11}(t^*/t_1)^2] \) in (5). Following Harberger (1964), this correction factor can be expressed as \(-a_1 \varepsilon / \eta_{11}\), where \( a_1 \) is \((x_1/(x_1 + x_2))\), or the fraction of money income accounted for by \( x_1 \); \( \varepsilon \) is the elasticity of supply of labor; and \( \eta_{11} \) is the own price elasticity of demand for \( x_1 \). Since \( \eta_{11} \) is necessarily negative, the correction factor will be positive but less than one so long as \(-a_1 \varepsilon < \eta_{11}\). A plausible value for \( a_1 \) is 0.20.

Assuming that the share of income spent on \( x_1 \) is 90 percent, then the correction factor will be 0.18/\( \eta_{11}\). Thus if the own-price elasticity of demand for \( x_1 = 0.75 \), the correction factor will be 0.24. The own-price elasticity of demand for \( x_1 \) would have to be less than 0.18 in order for an excise tax on \( x_1 \) to have a lower welfare cost than taxing both \( x_1 \) and \( x_2 \).

This is unlikely if 90 percent of income is being spent on \( x_1 \). This suggests that even after the distortionary costs of market failure have been internalized, it is still the case that an additional tax on environmental services will be welfare enhancing when compared to a tax on commodities only. Therefore, the "fully optimal" tax -- in a second-best world where raising revenue is costly -- will be higher than the Pigouvian tax. Note, however, than this is in addition to the existing tax on the commodity \( x \), which generates waste in consumption. This result contrasts with the findings of Bovenberg and de Mooij (1994).
Alternatively we can ask directly, what tax rates will minimize the welfare cost of raising revenue $R$ in this situation? For this we have well-known result that the welfare cost will be minimized when

$$\theta_1 = (\mu/\Delta)[x_1S_{22} - x_2S_{12}]$$  \[6\]

and

$$\theta_2 = (\mu/\Delta)[x_2S_{11} - x_1S_{12}]$$  \[7\]

where we denote the tax rates $t_i/p_i$ as $\theta_i$ and where $\Delta$ is the determinant of the Slutsky matrix and $\mu = \lambda/(1-\lambda)$ when $\lambda$ equals the marginal utility of income (Harberger, 1964).

And from this we can obtain the optimal tax result in the form

$$\frac{\theta_1}{\theta_2} = \frac{\varepsilon_{23} + \varepsilon_{21} + \varepsilon_{12}}{\varepsilon_{13} + \varepsilon_{21} + \varepsilon_{12}}$$  \[8\]

where $\varepsilon_{ij}$ is the compensated cross-elasticity $S_{ij}(p_i/x_i)$. This result allows us to include an assessment of the optimal tax from both distortionary and revenue perspectives. As above, we note that allocative efficiency requires that $p_2 = \theta_2$, the marginal environmental damage. And again, let’s assume that, rather than considering a pollution tax, this is accomplished by giving $x_2^*$ emissions permits to a private agent who then sells all the permits in a competitive market at the Pigouvian price $p_2^*$.

We want to answer the question whether the optimal tax on $x_2$ from a revenue raising perspective will give rise to a positive tax on $p_2^*$ in a world where $x_1$ is already taxed for revenue purposes. The question is, will $\theta_2$ be greater than zero? Obviously, when $\varepsilon_{13}$ is smaller than $\varepsilon_{23}$ then $\theta_2$ will be less than $\theta_1$, but that still requires that $t_2$ be greater than zero. In the case where a Pigouvian price $p_2^*$ is being charged for $x_2$, the fully optimal tax on $x_2$ from both distortionary and revenue raising perspectives would be $t_2^* = p_2^*\theta_2$ so that the tax directly on waste disposal is higher than the Pigouvian rate.

If, as is likely, both $x_1$ and $x_2$ are substitutes for leisure and their cross elasticities of demand with respect to the price of leisure is low compared to the cross elasticities of
demand across \( x_1 \) and \( x_2 \), then the ratio of \( \theta_1/\theta_2 \) will not be very different from unity (Harberger). There are circumstances for which one or the other optimal taxes will be negative, however. If \( \epsilon_{23} \) were greater than \( \epsilon_{21} + \epsilon_{12} \), while at the same time \( \epsilon_{13} \) is less than \( \epsilon_{21} + \epsilon_{12} \), then \( \theta_2 \) could be negative. But this result appears unlikely, and there is no obvious reason to believe this to be more likely for waste disposal services than for any other commodity.

IV. The general equilibrium model

The model above is illustrative, but because of the limitations implicit in the three-good model, the intuition regarding the substitutability among different goods and waste sinks, and its importance for the result, is constrained. We therefore need a more general model with which to consider more realistic situations. Consider a world with \( k+1 \) consumption goods where producer prices are \( q = (q_0, q_1, q_2, \ldots, q_k) \) for commodities 0, 1, ..., \( k \), and where the \( q_s \) reflect unit costs of production. In addition let consumer prices be \( p = (p_0, p_1, p_2, \ldots, p_k) \), where producer prices will differ from consumer prices since the government uses excise taxes \( t = (t_0, t_1, t_2, \ldots, t_k) \) to raise revenue \( R \). Therefore \( p_i = q_i + t_i \). Consider good zero to be leisure time (where time endowed is allocated to leisure or labor supply), and set \( q_0 = -1 \).

For the case of many identical consumers, let the household's utility function be \( U(z_1, z_2, \ldots, z_n) \) be represented in terms of the derived utility function for the \( k+1 \) consumption goods \( x_i \), and a vector of quantities of its own time, and write the utility maximization problem for the \( k \) consumption commodities according to the utility function \( U(x_0, x_1, x_2, \ldots, x_k) \) where \( x_i \) is the amount of the \( i \)th good consumed for goods \( x_0, x_1, x_2, \ldots, x_k \), subject to the budget constraint of \( p_0 x_0 + p_1 x_1 + \ldots + p_k x_k = 0 \) (Michael and Becker, 1973).

In addition to these commodities there exists a set of \( n-(k+1) \) natural environments which enter the economic model in two ways. First, because of their assimilative capacity, they serve as waste sinks for the disposal of the byproducts of consumption and
production of goods 0 through k. Second, they have an amenity value that enters the 
individual utility function directly as $a_{k+1}, a_{k+2}, ..., a_{k+n}$. Because they are congestible 
public goods, the amenity value of a particular waste sink $a_{k+i}$ may deteriorate due to the 
stock effect of the flow of waste services absorbed into $x_{k+i}$. Thus, these environmental 
assets are non-rival up to some point beyond which the congestion costs affect the amenity 
value of the asset. Although for simplicity we have assumed that congestion costs are 
limited to the amenity value (use and non-use values in consumption) of the environments, 
these congestion costs could also be modeled to impose costs on production by reducing 
the productivity of other factors (e.g., damages from water pollution on a fishery, climate 
change on agriculture).³

A. Fully optimal taxation

Because the waste disposal services are non-rival and non-exclusionary, we 
assume initially that their use is free ($p_i = 0$ for $i = k+2, ..., n$). The level of wastes produced 
in consumption of the $k+1$ goods varies across goods, as does the assimilative capacity of 
the different waste sinks, their amenity value, and the sensitivity of that amenity value to 
the level of waste. To simplify, waste generated in production is ignored in this model.

Assume that the number of individuals and the costs of coordinating individual 
choices imply that each individual takes the congestion of the $n-(k+1)$ environments as 
given. Then the individual optimization problem is

$$\text{Max } U(x_0, x_1, x_2, ..., x_n, a_{k+2}, a_{k+3}, ..., a_n),$$  

³ Restricting our analysis to direct amenity effects on utility does not limit the generality of our 
conclusions. A model where pollution affected factor productivity, or where the demand for waste 
disposal was in the form of derived demand from firms for an input into production would give similar 
results as has been demonstrated in the public finance literature (Diamond and Mirrless 1971). Indeed, 
since we are here considering the household to be a production unit, and where labor (leisure) is both an 
input into production and a good, then the differences between this model and a production-oriented one 
are reduced to differences in the boundaries of the firm.
subject to $\sum_{i} p_i x_i = 0$ for $i = 0, 1, 2, \ldots, k, k+1, k+2, \ldots, n$,

and where we assume for the moment that $p_{k+1} = p_{k+2} = p_{k+3} = \ldots = 0$. We can formulate the optimal tax problem as

$$\max \{ \max U(x, a) \mid p \cdot x = 0 \} \text{ subject to } (p - q) \cdot x = R \quad [10]$$

For our purposes it is useful to approach the analysis by way of the dual problem (see Auerbach, 1985) and define the indirect utility function as $V(U(x, a))$. Then we have

$$\max V(p, a) \mid (p - q) \cdot x = R \quad [11]$$

For the Lagrangian constrained optimization problem

$$V(p, a) - \mu [R - (p - q) \cdot x] \quad [12]$$

where $\frac{\partial V}{\partial a} = \frac{\partial U}{\partial a} \mid_{a(x, p, a)}$, and the first-order conditions with respect to each price are

$$-\lambda x_i + \sum_{h=k+1}^{n} m \frac{\partial U}{\partial a_h} \frac{\partial x_h}{\partial p_i} + \mu \left[ \sum_{j=1}^{n} t_j \frac{\partial x_j}{\partial p_i} + x_i \right] = 0,$$

for $i = 1, 2, \ldots, k, k+1, k+2, \ldots, n$.

and where $\lambda = dV/dy$ is the marginal utility of income for consumers. Because the environmental amenity is a non-rival good, the individual marginal utility is multiplied by the number of individuals, $m$. Rearranging terms to try and isolate $t$, we can write

$$\sum_{j=1}^{n} t_j \frac{\partial x_j}{\partial p_i} = \left( \frac{\lambda - \mu}{\mu} \right) x_i - \frac{m}{\mu} \sum_{h=k+1}^{n} \frac{\partial U}{\partial a_h} \frac{\partial x_h}{\partial p_i}.$$

[14]
Given that the $\partial x_j / \partial p_i$s are the elements of the Slutsky matrix, we can isolate $t_i$ on the left-hand side by using Cramer’s rule to get

$$
t_i = \sum_{j=1}^{n} \left[ \frac{\lambda - \mu}{\mu} x_j - \frac{m}{\mu} \sum_{h=k+1}^{n} \frac{\partial U}{\partial x_h} \frac{\partial x_h}{\partial p_i} \right] \frac{S_{ji}}{\Delta}. \tag{15}
$$

The inverse of the Slutsky matrix can be decomposed to write this as

$$
t_i = \sum_{j=1}^{n} \left( \frac{\lambda - \mu}{\mu} x_j \frac{S_{ji}}{\Delta} - \frac{m}{\mu} \sum_{h=k+1}^{n} \frac{\partial U}{\partial x_h} \frac{\partial x_h}{\partial p_i} \frac{S_{ji}}{\Delta} \right) \tag{16}
$$

where the $S_{ji}$’s are the adjoints of the Slutsky matrix $S$ and $\Delta$ is its determinant. By the rules for expansion of cofactors of determinants, we know that

$$
\sum_{j=1}^{n} \frac{\partial x_h}{\partial p_j} S_{ji} = \begin{cases} 
0 & \text{for } h \neq i \\
\Delta & \text{for } h = i
\end{cases} \tag{17}
$$

So that we can write the optimality conditions as

$$
t_i = \sum_{j=1}^{n} \left( \frac{\lambda - \mu}{\mu} x_j \frac{S_{ji}}{\Delta} \right) \text{ for } i = 1, 2, 3, \ldots, k \tag{18}
$$

and

$$
t_i = \sum_{j=1}^{n} \left( \frac{\lambda - \mu}{\mu} x_j \frac{S_{ji}}{\Delta} - \frac{m}{\mu} \frac{\partial U}{\partial x_i} \frac{\partial x_i}{\partial p_j} \right) \text{ for } i = k + 1, k + 2, \ldots, n. \tag{19}
$$

This result confirms that an optimal tax program should include taxes on environmental waste disposal that are separate from the taxes on the other commodities in the economy. Optimal taxes in equation [19] are separate and additional to those in equation [18]. Moreover, this optimality condition also shows the general result that the fully optimal tax on waste disposal will be higher than the Pigouvian price except when the first term on the
right-hand side of (19) is negative. This can be seen by recognizing that the second term in equation (19) is positive and represents the Pigouvian price. The first term in equation (19) is identical to that of equation (18) and will generally also be positive. In exceptional cases, the first term may be negative but that is an empirical question and there is no a priori reason to believe that it is more likely in the case of environmental waste services than it is for other commodities. Of course, the apparent separability of the two terms in (19), as well as the independence of equations (18) and (19) is only an analytical one. All the prices, quantities, and \( S_{ij} \)'s are interdependent and so the optimal tax rates depend on the actual equilibrium; and symmetrically the actual equilibrium depends on the optimal tax rates.

**B. Results under restrictive assumptions**

Results like those in (18) and (19) have sometimes been simplified by making the assumption that \( S \) is diagonal (Auerbach 1985; Sandmo 1975), and in addition by defining \( \phi \) to equal \( \lambda/\mu \), the ratio of the marginal utility of income to the marginal cost of raising a dollar of revenue. We divide through by \( p_i \), then substitute for \( p_i \) in the second term of the right-hand side the identity that will hold assuming allocative efficiency that \( p_j \lambda = \partial U/\partial \lambda_j \) for \( j < k \). We, therefore, can write the optimal tax conditions as:

\[
\theta_i = (1 - \phi) \frac{1}{\mu} - \phi \cdot m \frac{\partial U}{\partial x_i} \frac{\partial x_i}{\partial x_i} \quad \text{for } i = 1, 2, 3, \ldots, k, k+1, k+2, \ldots, k+n \quad [20]
\]

where once again \( \theta_i = t_i/p_i \). For the environmental sinks it is important to recognize that \( \theta_i = 1 \) because the disposal services are unpriced except for the tax being introduced. Since the left hand side equals one, the interpretation of how the right hand side adjusts to changes in \( \phi \) is altered. The first term on the right hand side, the distortionary component, reflects the well-known inverse elasticity rule for optimal taxation. The
second term, which is the corrective component of the tax, will equal zero for commodities 1 through k since they do not directly affect the environmental amenities k+2 through k+n. The second term on the right hand side (excluding \( \phi \)) represents the ratio of the marginal congestion cost to the marginal utility of waste disposal. In a first-best world with no distortionary cost to raising revenue, we can see that if there is no excess burden of taxation (if \( \phi = 1 \)) then the first term drops out and the fully optimal environmental tax will be given by the second term, or simply the “first-best” Pigouvian price.

For cases where \( 0 < \phi < 1 \) the optimality condition \([20]\) would appear to indicate that the corrective component of the tax will be less than the marginal environmental damage—and this has been the interpretation elsewhere in the literature (Bovenberg and de Mooij 1994; Bovenberg and van der Ploeg 1994, Sandmo 1975)—but this is incorrect. To interpret this result it is essential to recognize that the environmental waste sink is initially unpriced, so that \( \theta_i = t_i/p_i = 1 \) since \( t_i = p_i \). Therefore the left hand side of the equation equals one and is constant. The two factors \((1-\phi)\) and \( \phi \) are simply weights summing to one which are applied to the relative magnitudes of the distortionary component and the corrective component. The corrective component is equal to the marginal social damage from pollution divided by the marginal utility of waste disposal. If \( \phi < 1 \), or as \( \phi \) declines, the weight on the first term \((1-\phi)\) rises proportionally faster than the decline in the weight on the second term, so long as \( \varepsilon_{ii} < 1 \). In order for the sum of the two components to equal one, the second term must fall. The only way for this to occur is for the marginal pollution damage to decline, which implies a lower, not a higher, level of pollution. We can see that if \( \phi \) were to change from 1.0 to 0.9, the first term on the right hand side will become greater than 0.1. In order for the two terms to sum to 1, the second term being weighted now by 0.9, must decline below 1.0 for the two components to sum to 1. The only way for this to occur is for the optimum to shift to a lower level of pollution, thus implying a higher total tax rate. It follows that the higher is \( \phi \), the lower is the optimal level of pollution, and the higher is the efficiency gains from taxing environmental waste.
disposal. Exactly like other goods in the economy, the distortionary tax will raise the consumer price above the unit cost of the good or service.

For the case where there are no congestion costs associated with waste disposal in a particular sink (if waste flows were below the assimilative capacity), then the second term drops out and optimal taxation will revert to Ramsey prices -- the inverse elasticity rule. Since $\theta_i = 1$, we can see that this will hold when $\varepsilon_i = (1 - \phi)$ which is equal to $(\mu - \lambda) / \mu$, the marginal excess burden of taxation. Therefore even in the absence of congestion costs, a positive tax on waste disposal will be optimal since the own-price demand elasticity, $\varepsilon_{ii} = \frac{p_i}{x_i} \frac{\partial x_i}{\partial p_i}$, will initially be zero when starting at zero price and rise gradually as the tax rate increases.

Alternatively the result in (20) may be interpreted as a corrective component that equals the marginal social cost of pollution at the equilibrium and a distortionary component which weights the change in revenue by the marginal excess burden of existing taxes. The intuition of this can be shown graphically if we assume all cross effects are zero. In figure 1, $D$ is the demand for disposal of waste $x$ in a particular waste sink $(\frac{\partial U}{\partial x_i})$; MCC is the marginal congestion cost of waste for waste disposal $(m \frac{\partial U}{\partial x_i} \frac{\partial x_i}{\partial x_i})$, and NMEB is the net marginal excess burden for the tax system when environmental tax revenues are recycled through marginal reductions in existing tax rates, $NMEB = (\frac{dR}{dx})$.

First, we can see that the efficient level of pollution $x^*$ and the Pigouvian price $p^*$ will be optimal only when the marginal cost of raising a dollar of revenue equals the marginal utility of income, or when no distortions are necessary to raise revenue $R$. And

---

4 Sandmo's (1975) analysis fails to distinguish the object of taxation as being the services of the waste sink itself rather than as a tax on specific pollution-generating commodities, so that he does not recognize that the left-hand-side is constant and equal to one. Moreover, he concludes incorrectly that the optimal tax on such a commodity will be a weighted average of the optimal corrective tax and optimal revenue-raising tax. In his model, this would be true only if the terms being weighted were invariable or unchanged for different equilibria. The first-best Pigouvian tax will be optimal only if his first term is zero; and the Ramsey tax will be optimal only if the Pigouvian tax is zero (Sandmo 1975, p. 93).
second, in the absence of congestion costs (MCC = 0) over the entire range, then \( x' \) and \( t' \) will be optimal Ramsey prices—strictly as part of an optimal revenue raising program (where \( D = \text{NMEB} \)).

But aside from these special cases, the “fully optimal” tax \( t^{**} \) and level of waste disposal \( x^{**} \) will be higher than either \( p^* \) or \( t' \), occurring at the point where \( D = \text{MCC} - \text{NMEB} \), where condition (20) will also hold.\(^5\) This result is consistent with the partial equilibrium result of Lee and Misiolek (1986).

In sum, the second terms of (19) and (20) confirm the conditions for allocative efficiency in waste disposal. The first term indicates that broadly based optimal tax program will include taxes on these waste disposal services that will be additional to the price required to achieve allocative efficiency, as well as separate from the distortionary taxes on other goods in the economy. For revenue-neutral taxation up to the level of the Pigouvian tax, there will be two kinds of social benefits: one derived from allocative efficiency and the other from the appropriation by government of the rents on the waste sink’s assimilative capacity. Above this Pigouvian price the public finance benefits will continue to accrue, but will be gradually offset by marginal losses in allocative efficiency up to \( t^{**} \) and \( x^{**} \).

\[ C. \text{ Policy implications} \]

The presence of a double dividend from pollution taxes has the potentially attractive policy implication that a specific environmental tax can be justified solely on the basis of improving the efficiency of the overall tax system, thus making the burden of proof about the environmental damages less crucial in justifying a corrective tax. Indeed, for the numerical example illustrated in figure 1, the absence of congestion costs (MCC = 0) would lower only slightly the optimal revenue raising tax, \( t' \), below the Pigouvian tax,

\(^5\) This condition is not identical to the tax relation in [20] since the substitution of \( \lambda \) in [20] assumes allocative efficiency. Therefore they will be equal only when the optimality condition holds at \( t^{**} \).
Moreover, a zero tax on an environmental waste sink that is currently unpriced and untaxed will never be optimal (ignoring transaction costs) even in the absence of congestion costs since an initially small, incremental tax will always produce positive revenue and negligible excess burden—since \( e_{ii} \) in [20] will initially be zero.

The appeal of taxing pure rents from exogenously supplied resources is a well-known and long-established result from the literature on the taxation of exhaustible resource rents (Gray 1914, Gaffney 1967, Dasgupta and Heal, 1979). The analysis above also holds for other kinds of environmental services and other congestible public goods, whether they are supplied by nature or produced as public projects. An ocean fishery, for example, constitutes an exogenously provided congestible public good and taxing the rents from optimal harvesting of a fishery (i.e., by auctioning individual transferable quotas) would represent the appropriation of rents and produce the same benefits as indicated for a waste sink's assimilative capacity. Congestion pricing of highways or auctioning licenses to use segments of the electromagnetic spectrum are other examples where the appropriation of these rents can be used to improve the efficiency of the tax system.

In some cases of course, direct taxation of waste disposal may not be practical—in the same way that taxing many environmental amenities is not practical. In such cases, however, Pareto optimality may nevertheless be achieved through a set of indirect taxes on those commodities or inputs that have an effect on the amount of the externality produced (Holtermann, 1976). For example, if it is difficult to tax carbon emissions directly, the same result and incentives may be achieved by differential taxation of energy sources (coal, gas, biomass, solar) according to the net amount of carbon they emit when used. The result will be equivalent to a direct tax on carbon emissions (in the same way that public finance theory recognizes that proportional taxes on all commodities are equivalent to a tax on exogenous income). This discussion reinforces the importance of
carefully identifying the commodity being consumed as distinct from its related input (e.g., consuming energy not coal or natural gas), and in distinguishing the source of an externality (the dual use of natural environments for waste services and amenities) rather than a particular “dirty” commodity.

V. The “double dividend” debate

The question of how revenues from corrective taxes might be used was not considered by Pigou (1938) or most other economists interested in environmental taxation. Instead, they assumed for simplicity that revenues are returned lump-sum to the economy. Yet in addition to several early contributions (Sandmo 1975; Ng 1980; Terkla 1984), a number of economists have asked whether using these revenues to finance reductions in existing, revenue-raising taxes, might produce a secondary benefit by lowering the excess burden of the overall tax system (Jaeger 1995, Lee and Misiolek 1986, Oates 1993; Pearce 1991; Repetto et al 1992). They have argued that a ”double dividend" will result from "revenue recycling," seeing pollution taxes not only as corrective measures but as revenue-raising devices as well.

Recently, however, others have cautioned against the seductive appeal of this apparent environmental "free lunch." In general, these economists suggest that while revenue recycling of pollution tax payments may be preferred to a lump-sum transfer, it is unlikely that these gains from substituting pollution taxes for other taxes would more than offset the additional distortionary costs of the pollution tax. Attempts to explicitly model these tax interactions have led a number of researchers to the conclusion that environmental taxes exacerbate rather than alleviate distortions because of the interactions
between pollution taxes and pre-existing taxes. They conclude that the second-best optimal pollution tax is lower than the marginal environmental damage of pollution (Bovenberg and Mooij 1994; Bovenberg and Goulder 1996; Bovenberg and van der Ploeg 1994; Parry 1995).

However, in each of these cases the conclusion reached can be traced directly to the use of the externality metaphor. As a result, these models disregard the waste sink itself and instead characterize a world with “dirty goods” which are a kind of “commodity-cum-waste-disposal” combination that are not separable but occur in fixed proportions. They ignore the benefits of applying distortionary taxes separately and directly on waste disposal and they overlook the benefits of concentrating distortionary taxes on exogenously supplied assets. In contrast to the flexibility in the present analysis, these studies have modeled the environmental problem in a highly restrictive manner whereby a negative externality is created as a function of the total consumption of a specific polluting private good (Sandmo 1975; Bovenberg and Mooij 1994), a dirty public good (Bovenberg and van der Ploeg 1994), a polluting resource used in production (Bovenberg and Goulder 1996), or as a fixed proportion of industrial output (Ligthart and van der Ploeg, 1994; Parry 1995).

This implicit fixed proportions assumption guarantees that these models will reject the double dividend argument. The reason is clear: Under fixed proportions the two goods (a “dirty” consumer good and the waste sink where the waste is disposed of) are treated as essentially just one good. This leads directly (but incorrectly) to the conclusion that the total tax (distortionary plus corrective) on their “dirty-good-cum-waste-sink” will higher than the corrective tax on the good itself, but lower than the sum of the
distortionary tax on the good plus the first-best (Pigouvian) corrective tax on the pollution. It is easy to see how they arrive at this conclusion. For example, if automobiles are already being taxed optimally, then an additional tax on steering wheels will raise the excess burden of taxation since it will be identical to an additional tax on automobiles. If a “dirty good” is efficiently priced at unit cost (including the Pigouvian price for the pollution generated), and also taxed optimally from a revenue-raising perspective, then any additional tax on pollution will exacerbate the distortion already created by the existing distortionary tax, and a negative welfare effect will arise. But this is directly due to the combined effects of two misleading aspects of their models: the fixed proportions assumption and the failure to recognize that the waste sink itself should be taxed whether pollution is costly or not. Their models lead, quite correctly, to the conclusion that from a revenue raising perspective, a zero tax on steering wheels is optimal if automobiles are already taxed optimally.

The source of the error in this recent literature can be clarified with an example. Consider an environmental asset such as a river which provides a continuous source of water that households use to grow gardens. Assume that the river is owned by the central authority and can be sold or given to households. Assume also that the withdrawal of water from the river imposes a cost by reducing the productivity of a downstream fishery.

Obviously, in a first-best world it would be optimal to apply a Pigouvian price/tax to the allocation of water to achieve allocative efficiency between household uses and in-stream uses (e.g., supporting fish populations). If the government needed to raise revenues, the Pigouvian tax would be the best place to collect them since taxing the use of an exogenously supplied resource is possible without distortion to the economy up to the
Pigouvian rate. In a second-best world where the Pigouvian tax on water was insufficient to collect the revenues needed, a distortionary tax is called for, and this tax should be applied to garden tools, fertilizer, fish, as well as water and all other goods and services in the economy (with differential rates as indicated in the mathematical model above). Since water is sold at the Pigouvian price (reflecting the shadow cost of removing it from the river), the optimal distortionary tax will be an additional tax added to the Pigouvian price, raising the total tax above the Pigouvian rate. If the marginal cost of raising revenue were to rise, so should the distortionary tax on water and the other goods and services in the economy. Finally, consider how the optimal tax conditions would change if for some unrelated reasons the fishery went extinct so that no costs were involved with removing water from the river? In this case it would still be optimal to charge a fee for water as part of the distortionary tax system because, up to some level, the rents from this exogenously supplied asset will raise revenues at lower distortionary cost than taxes on other goods.

In this particular hypothetical example, Bovenberg, de Mooij, Goulder, Parry, and others might agree with the reasoning about optimal taxation of the commodity, water, as being exogenously supplied and therefore separable and directly taxable. So where is the discrepancy? The difference arises when one considers a case not where the river is a source of water, but where the river is instead a waste sink for by-products, say, from home consumption. Assume households buy wood to burn for home heating and then dispose of the ash in the river. In the model presented above, nothing changes. Whether as a waste sink or a source of water, the services of the river are valuable and separable from other commodities consumed.
But in the models constructed by Bovenberg and others are not able to describe the situation just posited, because their models do not allow waste sink services to be defined, allocated, or taxed separately from a given commodity. It is not possible to apply taxes to something that does not exist in the model, and in their models the waste sink does not exist as a separate "commodity." They use an externality model of a world with a "dirty good" thereby ignoring the separation of waste disposal services provided by the river from the goods that are accompanied by waste. Rather they conceive of a "commodity-cum-damage" good (where consuming a commodity harms fish directly) which, by way of its artificiality distorts their conclusions. In their world, waste disposal services cannot be taxed independently of commodities because they do not exist independently of those commodities. They view wood buying as killing fish directly. Thus the potential rent appropriation from the exogenous assimilative capacity of the river goes unnoticed. As a result their analysis of optimal distortionary taxation neglects the benefits of taxing waste disposal directly to raise revenue, in addition to the appropriate corrective tax associated with the harm inflicted on downstream fish by waste disposal.

Moreover, in their model if the disposal of ash in the river did not harm fish, then the optimal tax on disposing of waste in the river is zero, a result that ignores the potential for benefiting from concentrating taxes on the exogenously supplied waste sink. Furthermore given the assumptions in their model, as the cost of raising revenue increases they conclude that the total tax on wood will rise very slowly, because the corrective component will be reduced as the distortionary component rises. The intuition is that, as the marginal distortionary cost of taxing wood rises, it will be optimal to impose some of the distortionary cost on fish by reducing the corrective tax below the marginal damage.
The problem with this intuition is, again, that it misses the separability of utility derived from wood and that derived from waste disposal. In both cases we should begin by pricing each good or service according to its unit cost (whether production cost or downstream cost imposed on the fishery), and then by applying an optimal distortionary tax on that good or service.

True, as the cost of raising revenue rises the distortionary taxes on goods that are complements will rise more slowly than on substitutes, but only in extreme cases will the distortionary tax on one good be lowered to achieve the optimal mix of taxes for generating revenue. In contrast to the intuition advanced by Bovenberg and de Mooij (1994, p. 1085) that “the collective good of environmental quality directly competes with the other collective goods,” the correct intuition is to see that as the marginal cost of public funds rises, concentrating taxes on exogenously supplied assets will become more attractive, and this will reduce both the quantity of waste disposal demanded, and the marginal damage, below Pigouvian levels.

The externality metaphor also confuses the language we use for interpreting differences among the different models. When talking about the optimal distortionary tax we need to be clear as to whether we are keeping waste sinks and good separate, or whether we are lumping them together as one “good.” To be clear on how the findings presented here contrast with those of other models, consider the conclusions of Bovenberg and de Mooij (1994) where they rely on indirect income taxes to raise revenue. They conclude that the optimal direct tax on a “dirty good” should be lower than the Pigouvian rate (but the total tax, directly and indirectly, will be higher than the Pigouvian tax). By contrast, the analysis here demonstrates that the corrective tax applied directly to
waste disposal should always equal the Pigouvian price, or marginal environmental
damage, and that the indirect income taxes will apply to "dirty commodities" as well as the
waste sink directly. As a result, the total tax on dirty commodities and waste disposal will
be higher than the sum of the first-best Pigouvian tax plus the original distortionary taxes
on commodities.

The conclusion of Bovenberg and others can be arrived at by returning to the
mathematical model. We can see this by looking at equations [6] and [7] for the three-
good model and asking when θ₂ would be zero under optimal taxation. In equation [7]
we can see that this would be true when x₂S₁₁ = x₁S₁₂, which would be the case when the
quantity demanded of x₂ is in fixed proportions to x₁. Assume that x₂ is produced in some
fixed proportion β to x₁ (x₂ = βx₁) and that S₁₁ is some value α. Given fixed proportions,
it follows that S₁₂ = αβ. Substituting in to x₂S₁₁ = x₁S₁₂ we have αx₂ = αβx₁, and
substituting βx₁ for x₂ we get αβx₁ = αβx₁. Therefore, the assumption of fixed
proportions between X₁ and X₂ gives rise to an optimal tax t₂ = 0 when t₁ = t*₁ or that a
tax on x₂ will effectively raise the excess burden of an existing tax on x₁.⁶

In short, although the results of these studies, while consistent with the
assumptions on which they are based--including the empirically estimated model of
Bovenberg and Goulder (1996)--produce deceptive conclusions because of their
unrealistic assumption of fixed proportions between goods and waste disposal, and
ignoring the potential for appropriating resource rents. The case of fixed proportions can

⁶ It is worth noting that one additional limitation of these models is that, as constructed, they would be
unable, for example, to represent a system of tradable emissions permits for a particular environmental
sink since the demand for waste disposal services is absent.
be seen as just a special case in the model presented above, one where the optimal total
tax (corrective and distortionary) may, indeed, be less than the sum of the first-best
Pigouvian tax and the second-best distortionary tax on the commodity itself.

VI. Conclusions

This paper has shown that the integration of corrective environmental taxation and
optimal tax theory must begin by recognizing that environmental pollution problems are
market failures that arise in the absence of property rights for the assimilative capacity of
environmental waste sinks to absorb and eliminate the residual byproducts of consumption
and production. From this perspective it can be shown that the introduction of a Pigouvian
tax on waste disposal both restores allocative efficiency and appropriates the rents from
the use of these waste sinks, producing two social benefits when such a tax is introduced
in a revenue neutral way. In general, the "fully optimal" tax will be higher, and the level of
pollution lower, than the Pigouvian price.

The innovation in this analysis, and the conflicting results in the prior literature on
these issues, can be traced directly to the need to recognize that the notion of an
externality is an abstract metaphorical device that carries with it some misleading and
unfortunate assumptions.

The conclusions of this analysis can be applied to a wide range of congestible
public goods such as ocean fisheries, public highways, or the radio spectrum. Even in the
absence of congestion costs, or when congestion costs are uncertain or unknown, taxation
of environmental resources or other public goods should be part of an optimal revenue
raising tax program because they broaden the tax base and appropriate the rents from
exogenously supplied assets.

Environmental waste sinks provide essential services and are an ubiquitous and
integral part of economic life. But their importance from a public finance perspective, and
the unnecessarily high excess burden that results when not taxing them, has previously not been recognized or fully understood. For large categories of wastes and sinks such as atmospheric disposal of carbon gases, the inefficiencies that currently exist, and hence the potential social benefits of correcting them, may be large. Indeed, based on tax efficiency grounds alone, it has been estimated that an optimal global carbon tax would reduce carbon emissions by 37 percent and produce $2.1 trillion in welfare benefits over the next 100 years (Jaeger, 1995).
REFERENCES


Figure 1. Optimal taxation of environmental waste disposal

D, demand for waste disposal services
NMEB, net marginal excess burden
MCC, marginal congestion cost

quantity of waste

$/$x

t**, p*, t'
A series of papers written by members of the Department of Economics on topics that do not pertain directly to less developed countries. From time to time documentation for computer programs and other research tools developed by members of the department will be distributed in this series as Special Research Papers and denoted by the letters RPS. A copy of any paper (and/or a reprint of the published version) will be mailed on request. See the order blank for further details.

1984-1996 Research Papers


RP-166  Thomas C. Pinckney and Peter K. Kimuyu, "Land Tenure Reform in East Africa: Good, Bad, or Unimportant?" June, 1993.


** Reprint only available
Center for Development Economics
Department of Economics
Williams College
RESEARCH MEMORANDUM SERIES

A series of papers written by members of the Department of Economics on topics pertaining to the economics of less developed countries. A copy of any paper (and/or a reprint of the published version) will be mailed on request. See the order blank for further details.

1984-1996 Research Memorandum


RM-93* Stephen R. Lewis, Jr., Taxation for Development, Oxford University Press, 1984 (available only through the publisher).


<table>
<thead>
<tr>
<th>Report Number</th>
<th>Title</th>
<th>Author(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM-150</td>
<td>John Sheahan, &quot;Effects of Adjustment Programs on Poverty and on Autonomy: Chile, Mexico, and Peru,&quot;</td>
<td>January, 1996.</td>
<td></td>
</tr>
<tr>
<td>RM-152</td>
<td>Ralph Bradburd, &quot;Regulatory Rigidity: Causes, Consequences and Implications For Public Policy in Developing Countries,</td>
<td>February, 1996.</td>
<td></td>
</tr>
</tbody>
</table>

* Reprint only available
ORDER BLANK
FOR RESEARCH MEMORANDA AND RESEARCH PAPERS

Please send the indicated number of copies of each paper.

RM-69  RM-95  RM-121  RP-09  RP-35  RP-61  RP-87  RP-113  RP-139  RP-165

RM-142  RM-148
RM-143  RM-149
RM-144  RM-150
RM-145  RM-151
RM-146  RM-152
RM-147  RM-153

My correct mailing address is:

MAIL THIS COMPLETED ORDER BLANK TO THE ADDRESS IN THE TOP LEFT CORNER.

* Please Note: There is a 10 paper limit with only one copy of each paper.