

ENVIRONMENTAL POLICY MAKING IN A SECOND-BEST SETTING

LAWRENCE H. GOULDER*

Stanford University, Resources for the Future, and NBER

This paper uses analytically tractable and numerically solved general equilibrium models to examine the significance of pre-existing distortions in factor markets for revenue-neutral environmental tax reforms and for various policies involving pollution quotas and permits. Results indicate that pre-existing factor taxes generally raise the costs of these environmental policies. This reflects a *tax-interaction effect*: the lowering of real factor returns resulting from the higher output prices occasioned by environmental taxes and other regulations. The *revenue-recycling effect* – stemming from the use of environmental tax revenues to finance cuts in pre-existing factor taxes – helps reduce policy costs, but under plausible assumptions does not eliminate the costs of such policies: the double dividend does not materialize. Even if it does not produce a double dividend, the revenue-recycling effect is important for reducing policy costs. Policies that fail to exploit the revenue-recycling effect suffer significant disadvantages in terms of efficiency. Like environmental taxes, freely allocated (or grandfathered) pollution quotas or permits, for example, produce a costly tax-interaction effect, yet such quotas or permits do not enjoy the offsetting revenue-recycling effect. Auctioning the permits or quotas makes possible the revenue-recycling effect and allows given pollution-abatement targets to be achieved at lower cost. The failure to exploit the revenue-recycling effect can alter the sign of overall efficiency impact. Indeed, if marginal environmental benefits from pollution reductions are below a certain threshold value, then any level of pollution abatement through freely allocated quotas or permits is efficiency-reducing. The tax-interaction effect is relevant to government regulation outside the environmental area. To the extent that regulations on international trade or agricultural production raise output prices and thereby reduce real factor returns, these regulations exacerbate the factor-market distortions from pre-existing taxes and thus involve higher social costs than would be indicated by partial equilibrium analyses.

* The author gratefully acknowledges the U.S. National Science Foundation (Grant SBR9613458) and U.S. Environmental Protection Agency (Grant R825313-01) for financial support.

I. Introduction

Economists have long been interested in ways that taxes and other policy instruments can address environmental problems associated with externalities. This interest dates back at least to Pigou (1938), who showed that taxes could usefully internalize externalities and thereby “get the prices right” – that is, bring prices into alignment with marginal social cost. In the last two decades, there has been increased attention to other, non-tax market instruments – including tradeable emissions permits and deposit-refund systems – as tools for dealing with environmental problems in an effective way.

The tradition in environmental economics since Pigou has been to analyze environmental policies with an almost exclusive attention to the externality of immediate concern and little attention to other distortions or market failures. However, in recent years economists have come to recognize the importance of interactions between environmental policies and other (non-environmental) distortions in the economy. In particular, there has been increased attention to the interconnections between environmental taxes and the distortions imposed by pre-existing income or commodity taxes.

Perhaps the first to consider closely these interactions was Sandmo (1975), although the Sandmovian issues and insights were largely ignored until recently. Sandmo analyzed the optimal setting of commodity taxes when the production or consumption of one of the commodities generates an externality. He showed that when the government’s need for revenue exceeds the level that can be generated by taxes set according to the “Pigovian principle” (that is, set equal to the marginal environmental damages), then the optimal tax system includes taxes not only on externality-generating goods and services but on other goods and services as well. In Sandmo’s analysis, the optimal tax rates on environmentally damaging activities and on ordinary activities are intimately connected.

The interconnections between ordinary and environmental taxes, so central to Sandmo’s optimal tax result, also figure importantly in the analysis

of the impacts of marginal (that is, less than globally optimizing) environmental reforms. A line of research conducted during this decade shows that one cannot effectively evaluate the impacts of many environmental reforms without paying attention to the magnitudes and types of existing, distortionary taxes such as income, payroll, or sales taxes. There are two important interconnections here. First, as Terkla (1984), Lee and Misiolek (1986), Oates and Schwab (1988), Oates (1993), Repetto *et al.* (1992), and others have emphasized, the presence of distortionary taxes introduces opportunities to use revenues from new environmental taxes to finance cuts in the marginal rates of the ordinary distortionary taxes. To the extent that revenues from the environmental tax finance marginal rate cuts of this kind, some of the distortions that the ordinary taxes would have generated are avoided. This *revenue-recycling effect* suggests that the overall *gross*¹ costs of environmental taxes will be lower in a second-best world than in a first-best setting.

However, a second interconnection works in the opposite direction. Recent work by Bovenberg and de Mooij (1994a), Bovenberg and van der Ploeg (1994), Bovenberg and Goulder (1996, 1997), Parry (1995, 1997), and others² points out that environmental taxes are implicit taxes on factors of production such as labor and capital. By raising the costs of production and the costs of goods in general, environmental taxes (and many other environmental regulations) reduce after-tax factor returns much like explicit factor taxes do. Thus, environmental taxes function as increments to existing factor taxes, tending to magnify the factor market distortions already generated by pre-existing factor taxes. The additional efficiency costs of environmental taxes associated with the reduction in factor returns brought about by higher costs and output prices has been called the *tax-interaction*

¹The modifier "gross" indicates that the costs do not net out the policy-generated benefits associated with an improved environment.

²For reviews of this new literature, see Oates (1995) and Goulder (1995a).

effect.³ The larger the rates of pre-existing factor taxes, the larger the tax-interaction effect, and thus the higher the gross costs from environmental taxes and other regulations that reduce after-tax returns to factors. The tax-interaction effect implies that, for any given method of recycling the revenues, the gross costs of environmental taxes are higher in a second-best setting with pre-existing factor taxes than they would be if there were no prior taxes on factors. As will be discussed in more detail later in this paper, the tax-interaction effect tends to be of greater magnitude than the revenue-recycling effect; that is, it is only partly offset by the revenue-recycling effect.

The revenue-recycling and tax-interaction effects are highly relevant to the evaluation of currently debated environmental policy alternatives. In discussions of carbon tax policies, for example, there has been great interest in the possibility that judicious recycling of the revenues from carbon taxes could cause the overall gross costs of these policies to become zero or negative. Proponents of carbon taxes certainly would welcome this result, since it implies that policy makers must only establish that there are non-negative environment-related *benefits* from the carbon tax policy to justify the policy on efficiency grounds. Given the vast uncertainties about the environment-related benefits from carbon abatement, it would significantly reduce the information burden faced by policy makers if they simply needed to determine the sign, rather than magnitude, of the environmental benefits. If one ignores the tax-interaction effect and concentrates only on revenue-recycling (and the revenue-recycling effect), the prospects for a zero-cost carbon tax will seem quite good. But the tax-interaction effect also has a key role here and, as will be discussed below, this latter effect significantly reduces the scope for the zero-cost result. This does not mean that carbon taxes are a bad idea; it only means that justifying these taxes requires attention to the magnitudes (not just the sign) of the environmental benefits.

³Parry (1995) was the first to isolate the tax-interaction and revenue-recycling effects in evaluating the second-best welfare impacts of environmental taxes. He termed these the “interdependency” and “revenue” effects.

A second area where the revenue-recycling and tax-interaction effects are important is in the choice among alternative policy instruments. Consider, for example, the choice between pollution tax policies (or pollution permits policies involving the auctioning of permits by the government) and freely allocated (or “grandfathered”) emissions permits. The former policies raise revenue and thus are capable of taking advantage of the revenue-recycling effect. The latter policies, in contrast, do not raise revenue and therefore cannot exploit this effect. As discussed below, the tax-interaction effect arises under both policies, but only under the revenue-raising policies is the (costly) tax-interaction effect offset by the revenue-recycling effect. Recent work by Parry (1997), Goulder, Parry, and Burtraw (1997), Parry, Williams, and Goulder (1998), Fullerton and Metcalf (1997), and Goulder *et al.* (1998) reveals that the presence or absence of the revenue-recycling effect can fundamentally affect the overall efficiency impacts of these policies.⁴ In fact, when marginal benefits from pollution abatement fail to exceed a certain threshold value, pollution permit policies that fail to enjoy the revenue-recycling effect may be unable to produce any efficiency improvements, no matter what the level of pollution abatement!⁵ This analysis shows that the decision to give out pollution permits free rather than to auction them (or, equivalently, to employ a pollution tax) comes at a high price in terms of efficiency, and indeed may affect the sign of the overall efficiency impact. There may be other considerations (such as distributional impacts) that tend to support the use of grandfathered permits rather than auctioned permits or

⁴Fullerton and Metcalf explain differences in efficiency outcomes in terms of whether policies generate privately-retained scarcity rents, rather than in terms of whether they exploit the revenue-recycling effect. As discussed in Section III, the two issues are intimately connected.

⁵This result, for pollution permits, was foreshadowed by Bovenberg and Goulder’s (1996) finding that a carbon tax with lump-sum replacement of the revenues will be efficiency-reducing if marginal environmental benefits from carbon abatement are below a certain threshold (about \$50 per ton). Parry (1997) recognized that the same formal analysis applies to the case of pollution quotas and grandfathered pollution permits; thus the same “threshold” issue arises.

pollution taxes, but this recent literature indicates that the efficiency disadvantage of grandfathered permits is more significant than was previously recognized.

This paper examines the efficiency impacts of pollution taxes and some other pollution-control policies in a second-best setting with prior distortionary taxes in factor markets. It aims to articulate and pull together some key ideas from recent papers on this subject. The next section provides a simple analytical framework for defining and evaluating the efficiency effects of environmental taxes and quotas (or tradeable permits) in this second-best setting. Section III then elaborates on these results, first by offering additional interpretation related to environmental taxes and the double dividend issue, and then by considering the significance of second-best issues for the choice between taxes and other, non-tax instruments for environmental protection. Section IV briefly depicts some results from investigations that apply this second-best framework to assess the efficiency impacts of environmental taxes and regulations. It first considers the impacts of revenue-neutral environmental taxes; then examines potential impacts of pollution permits, with a focus on the efficiency implications of the decision whether to auction or freely offer the permits. The final section offers conclusions.

II. An Analytical Framework

Here we present a simple analytical framework for assessing the impacts of environmental taxes and quotas in a second-best setting with prior distortionary taxes. The framework is based on an analytical model presented in Goulder, Parry and Burtraw (1997), which we hereafter will refer to as GPB.

A. The basic model

A representative agent model is assumed in which household utility is

$$U(X, Y, A) + V(Q) \tag{1}$$

where $U(\cdot)$ is quasi-concave, $V(\cdot)$ is concave, and both functions are continuous. X and Y are market goods, ℓ is leisure or non-market time, and Q is the quality of the environment. Separability between environmental and non-environmental goods implies that the demand functions for X , Y and ℓ are independent of Q .

X and Y are produced by competitive firms using labor as the only input.⁶ The marginal product of labor in both industries is constant and unaffected by environmental quality. Normalizing units to imply transformation rates of unity, we can write the economy's resource constraint as:

$$T = X + Y + \ell \quad (2)$$

where T is the household time endowment ($T - \ell$ is labor supply).

The production of X causes waste emissions that harm the environment; that is:

$$Q = Q(X) \quad (3)$$

Where $Q_x < 0$.⁷ From (1) and (3), we can define marginal environmental damages from production of X in terms of dollars by

$$D(X) = \frac{1}{\lambda} V' Q_x \quad (4)$$

⁶ The focus of the present paper is environmental regulation of competitive enterprises. Oates and Strassman (1984) examined the impacts of environmental policies under alternative market structures. That paper included an analysis of the impacts of regulation in a monopoly setting, and showed how in that setting environmental regulation generates costs associated with the reduction in the monopolist's supply of output. Optimal regulation must balance these costs against the benefits from pollution reduction. More recently, Browning (1997) and Fullerton and Metcalf (1997) have examined interactions between new regulations and pre-existing tax distortions in the presence of monopoly.

⁷ Therefore, reducing waste emissions requires a reduction in output. In a more general formulation, this could also be achieved by substituting waste emissions for other inputs in production

where λ is the marginal utility of income. We make the usual assumption that $D'(X) \geq 0$. In the absence of policy intervention, there is assumed to be no internalization of environmental damages by firms or households.

Finally, the government has an exogenous total revenue requirement TR , levies a proportional tax of τ_L on labor income, and regulates X . For our purposes it does not matter what TR is used for; we assume it is returned to households as a lump sum transfer.⁸

B. Impacts of Pollution Taxes (with Revenues Used to Cut Marginal Tax Rates)

Now consider a revenue-neutral policy involving a new environmental tax τ_X per unit of output X . The environmental tax is accompanied by a reduction in the labor tax τ_L , where the reduction is such as to make the overall policy revenue-neutral. Normalizing the gross wage to unity, we can express the household budget constraint as:

$$(1 + \tau_X)X + Y = (1 - \tau_L)(T - \ell) + TR \quad (5)$$

Households are assumed to maximize utility (1) subject to their budget constraint (5), taking environmental quality as given. This yields the first order conditions

$$U_X = (1 + \tau_X)\lambda; \quad U_Y = \lambda; \quad U_\ell = (1 - \tau_L)\lambda \quad (6)$$

From (5) and (6) we can implicitly derive the (uncompensated) demand functions

$$X(\tau_X, \tau_L); \quad Y(\tau_X, \tau_L); \quad \ell(\tau_X, \tau_L) \quad (7)$$

⁸ An alternative specification would incorporate TR as a public good in the household utility function. This produces the same results as in our model, since TR is held constant.

Government revenues are the sum of labor and pollution tax revenues. Therefore government budget balance requires

$$TR = \tau_L(T - \ell) + \tau_X X \tag{8}$$

Since the policy is revenue-neutral, TR is kept constant. Substituting (7) in (8) and totally differentiating the resource constraint (2) while holding TR constant gives:

$$\frac{d\tau_L}{d\tau_X} = - \frac{X + \tau_X \frac{dX}{d\tau_X} - \tau_L \frac{\partial \ell}{\partial \tau_X}}{T - \ell - \tau_L \frac{\partial \ell}{\partial \tau_L}} \tag{9}$$

This expression can be combined with equations (1), (2), (3), y and (7) (see GPB) to yield:

$$\frac{1}{\lambda} \frac{dU}{d\tau_X} = \underbrace{(D - \tau_X) \left(-\frac{dX}{d\tau_X} \right)}_{dW^P} + M \underbrace{\left(X + \tau_X \frac{dX}{d\tau_X} \right)}_{dW^R} - \underbrace{(1 + M)\tau_L \frac{\partial \ell}{\partial \tau_X}}_{\partial W^I} \tag{10}$$

where

$$M = \frac{\tau_L \frac{\partial \ell}{\partial \tau_L}}{T - \ell - \tau_L \frac{\partial \ell}{\partial \tau_L}} \tag{11}$$

M represents the marginal welfare cost per dollar of revenue from labor taxation. The numerator in the expression for M is the welfare cost of the

policy change. This is the increase in leisure multiplied by τ_L , the wedge between the gross and net wage. The denominator is the overall increase in government revenue from a marginal increase in the labor tax.

Equation (10) is the overall efficiency or welfare impact of the policy change. The equation divides this impact into three components. The first is the *Pigovian* (or partial equilibrium) effect ∂W^P . This is the reduction in X from a marginal increase in the environmental tax, multiplied by the wedge between marginal social cost and the demand price, or marginal social benefit. The second is the gain from the (marginal) *revenue-recycling effect*, ∂W^R . This is the product of the efficiency value per dollar of tax revenue (the marginal welfare cost of taxation) and the incremental pollution tax revenue. The third is the (marginal) *tax-interaction effect*, ∂W^I . The pollution tax raises the demand price of the good X . When X and leisure are substitutes, the higher price of X implies a reduction in the real wage, which implies an increase in leisure. This in turn exacerbates the welfare cost of the labor tax by $\tau_L \frac{\partial \ell}{\partial \tau_X}$. This also reduces labor tax revenues by $\tau_L \frac{\partial \ell}{\partial \tau_X}$. The tax-interaction effect is the welfare loss from these two impacts.

We can use the information in (10) to compare the magnitudes of the revenue-recycling and tax-interaction effects. ∂W^I can be manipulated (see GPB) to give the following approximation for the tax-interaction effect:

$$\partial W^I = \phi_X MX ; \quad \phi_X = \frac{\eta_{Xl}^c + \eta_{Ll}}{\frac{X}{X+Y} \eta_{Xl}^c + \frac{Y}{X+Y} \eta_{Yl}^c + \eta_{Ll}} \quad (12)$$

where η_{Yl}^c and η_{Xl}^c are the compensated elasticity of demand for X and Y with respect to the price of leisure, and η_{Ll} is the income elasticity of labor supply. ϕ_X is a measure of the degree of substitution between X and leisure relative to that between aggregate consumption and leisure. ϕ_X equals unity when X and Y are equal substitutes for leisure (equals) and is greater (less)

than unity when X is a relatively strong (weak) substitute for leisure (that is, when η_{Xl}^c is greater (less) than 1). When η_{Xl}^c equals η_{Yl}^c , equation (12) reduces to $\partial W^t = MX$. Equation (10) indicates that under these circumstances the tax-interaction and revenue-recycling effects exactly cancel each other out if pollution abatement is incremental, that is, if $\tau_x = 0$. However, for more than incremental abatement (that is, for $\tau_x > 0$), the tax-interaction effect is larger than the revenue-recycling effect (by the amount $M\tau_x \frac{dX}{d\tau_x}$). The pollution tax affects the relative prices of consumer goods, “distorting” the household’s consumption choice as well as its labor-leisure choice.⁹ Recycling the revenues help return the real wage to its original value and thereby mitigates the labor-market distortion, but such recycling does not undo the change in relative consumer good prices and the associated “distortion” in consumption.¹⁰ For this reason the revenue-recycling effect only partly offsets the tax-interaction effect when the level of abatement is non-incremental.

This means that pre-existing taxes usually imply that the overall efficiency gains from environmental taxes are lower than in a first-best setting, unless

⁹ The word “distort” is in quotes to acknowledge that we are ignoring environment-related benefits here. The changes in relative prices of commodities occasioned by the pollution tax may contribute to higher gross costs, but these same relative price changes may bring about an overall efficiency improvement, since overall efficiency incorporates the environment-related benefits that result from the relative price changes.

¹⁰ The tax-interaction effect exceeds the revenue-recycling effect to the extent that the revenue-neutral reform causes relative prices to depart from their Ramsey optimum. In this model, if the two consumer goods are equal substitutes for leisure, the Ramsey optimum calls for uniform taxation of these two goods or, equivalently, simply a tax on labor. If the two consumer goods are not equal substitutes for leisure, the Ramsey optimum will differ. In particular, if the dirty good is a weaker substitute for leisure than the clean good, the Ramsey optimum calls for (on non-environmental grounds) higher taxation of the dirty good than the clean good. Under these conditions, if initially the two goods were equally taxed (or, equivalently, if the only tax in place were the labor tax), then imposing a new tax on the dirty good could produce a tax-interaction effect of smaller magnitude than the revenue-recycling effect. For a more detailed discussion, see Bovenberg and Goulder (1998).

the environmentally damaging good is a sufficiently weak substitute for leisure (that is, unless ϕ_x is sufficiently below unity). This is the first main result.

C. Impacts of Non-Auctioned Pollution Quotas (or Pollution Taxes with Revenues Returned Lump-Sum)

Now consider, in contrast with the pollution tax case, the situation where a binding, non-auctioned quota is imposed. The analysis is formally the same for a pollution tax policy, where the revenues are returned lump-sum rather than in the form of marginal rate cuts.¹¹ It is also the same for the case of freely allocated (or grandfathered) emissions permits.¹²

We define this quota by a virtual tax τ_x ; that is, by the tax that would induce the equivalent reduction in X as the quota. This quota produces rents of $\pi = \tau_x X$, which are retained by households (who own firms). Here we assume that these rents are not taxes, so that all of π becomes household income.¹³ Therefore π appears as an exogenous lump-sum component of income in the household budget constraint. The household demand functions can now be summarized by:

$$X(\tau_x, \tau_L, \pi); \quad Y(\tau_x, \tau_L, \pi); \quad \ell(\tau_x, \tau_Y, \pi) \quad (7')$$

¹¹ See GPB, appendix B.

¹² This framework abstracts from the heterogeneity of production or abatement cost functions across firms in a given industry: all producers of a given good are regarded as identical. Considerations of heterogeneity can importantly influence the choice among policy instruments. In particular, heterogeneous abatement cost functions make a policy of tradeable pollution permits attractive relative to one of fixed pollution quotas, since trades can be a key mechanism for creating production efficiency (equality of marginal abatement costs). These heterogeneity issues are important, but can largely be examined separately from the issues emphasized in this paper.

¹³ The taxation of rents does not change the qualitative results, except in the limiting case where 100 percent of the rents are taxes. This limiting case corresponds to the pollution tax case already examined. For further discussion of this issue, see GPB and Parry *et al.* (1998).

The key compared with the previous case is that the quota policy generates no revenue. Therefore the government budget constraint is:

$$TR = \tau_L (T - \ell) \tag{8'}$$

Again we consider a revenue neutral incremental increase in τ_x . Following the same procedure as for the pollution tax yields:

$$\frac{d\tau_L}{d\tau_x} = \frac{\tau_L \frac{\partial \ell'}{\partial \tau_x}}{T - \ell - \tau_L \frac{\partial \ell}{\partial \tau_L}} \tag{9'}$$

Since $\partial \ell' / \partial \tau_x$ is (in general) positive, the revenue neutral quota induces an overall increase, rather than a decrease, in the labor tax.

Following the analogous procedure as for the pollution tax yields the following expression for the general equilibrium welfare change from the policy:

$$\frac{1}{\lambda} \frac{dU}{d\tau_x} = \underbrace{(D - \tau_x) \left(-\frac{dX}{d\tau_x} \right)}_{dW^P} - \underbrace{(1 + M)\tau_L \frac{\partial \ell}{\partial \tau_x}}_{\partial W^I} \tag{10'}$$

The quota policy leads to a Pigovian welfare effect and a tax-interaction effect. The key difference between (10') and (10) is that the quota does not generate a revenue-recycling effect to counteract the tax-interaction effect.

D. Welfare Implications of Policy Choice

The presence or absence of the revenue-recycling effect can importantly

affect the efficiency outcomes of environmental policies. The above results indicate that given levels of pollution abatement are achieved at lower cost through a pollution tax (with revenues returned through cuts in the labor tax) than through a pollution quota. Under the two policies, the Pigovian gain and tax-interactions are the same, but the revenue-recycling effect applies only under the pollution tax.

In fact, as indicated in the introduction, the presence or absence of the revenue-recycling effect can determine the sign of the overall efficiency impact. An efficiency improvement will occur if and only if the combination of the Pigovian gain and the revenue-recycling effect (if applicable) is larger than the tax-interaction effect. The revenue-recycling effect may be necessary to meet this condition. If the revenue-recycling effect is absent, and the Pigovian gain is less than the tax-interaction effect, then the environmental policy will be efficiency-reducing. Note that the tax-interaction effect is non-incremental, even at the first incremental amount of abatement, as can be seen from equation (10) or (10'). This means that when the revenue-recycling effect is absent, the Pigovian gain –or the marginal environmental benefits from reducing pollution (net of direct abatement costs)– must exceed a certain positive value to allow an efficiency improvement.

Under traditional Pigovian analysis, the marginal cost of the first units of pollution abatement is zero; hence environmental regulation can increase welfare so long as the marginal environmental benefits are positive. In a second-best setting, if X is an average substitute for leisure, a pollution tax with revenues recycled through income tax cuts also has the property that the marginal cost of pollution abatement is zero at the first unit of abatement. Thus in this case, the overall efficiency impact will be positive if marginal environmental benefits are positive (and the amount of abatement is not too great). However, in the pollution quota case, the absence of the revenue-recycling effect means that the incremental welfare change from regulation is positive only if marginal benefits from abatement exceed a certain

threshold value. The threshold value is the tax-interaction effect at $\tau_x = 0$.¹⁴

How large is this critical value? With a value of 0.3 assumed for the marginal welfare cost of labor taxation¹⁵, the analytical framework above implies that the critical value of marginal environmental benefits is 60 percent, 30 percent, or 15 percent of firms' marginal production costs, when the elasticity of demand for the polluting good is 0.5, 1, or 2, respectively.¹⁶ We look more closely at these critical values in Section IV, where consider specific regulatory contexts.

As mentioned at the beginning of this section, the analysis of pollution quotas is formally identical to that for a pollution tax whose revenues are returned lump-sum, or for a set of freely offered or grandfathered pollution permits. Also, the analysis for the pollution tax is the same as that for a set of auctioned pollution permits. Thus, the revenue-recycling effect accounts for the differences between pollution taxes or auctioned pollution permits (with revenues applied to labor tax cuts), on the one hand, and pollution quotas, grandfathered pollution permits, or pollution taxes with revenues returned lump-sum, on the other.

E. A Graphical Illustration of the Main Findings

Some key results from the analytical model are:

1. For incremental pollution abatement through a pollution tax (with revenues devoted to cuts in the labor tax), the marginal tax interaction effect is exactly offset by the revenue-recycling effect (if X and Y are equal substitutes for leisure).

¹⁴ It is implicitly assumed that marginal environmental benefits are constant or decreasing in the amount of abatement.

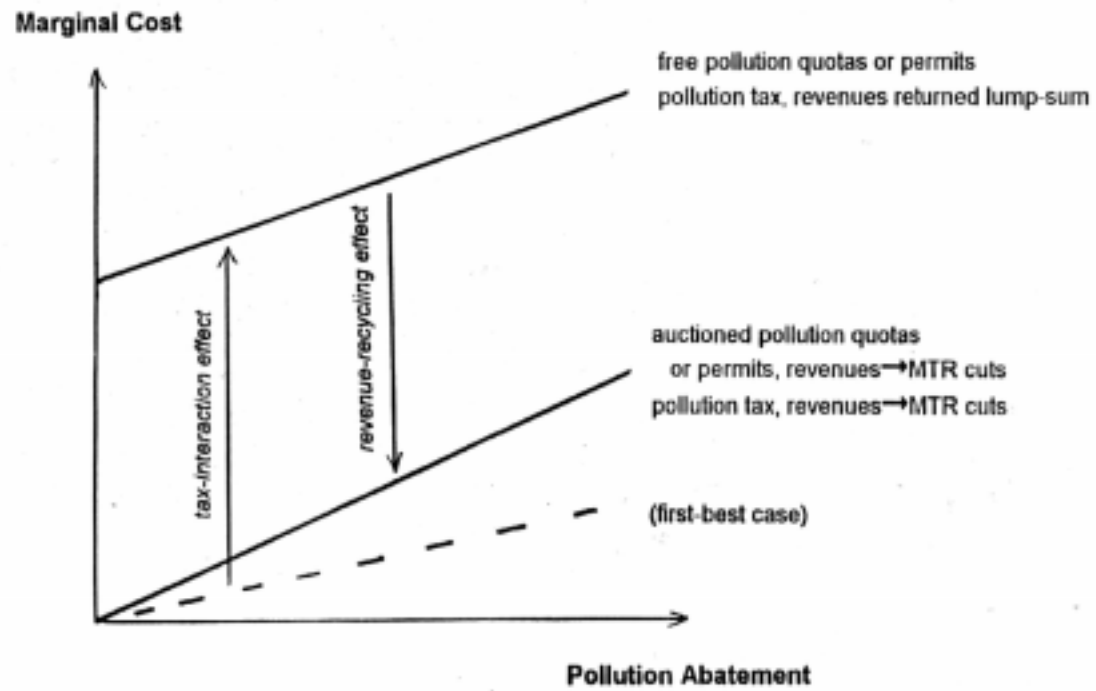
¹⁵ This value is consistent with values obtained in empirical investigations. See, in particular, Ballard *et al.* (1985) and Browning (1987).

¹⁶ For further discussion, see GPB.

2. For non-incremental pollution abatement through the pollution tax, the marginal tax interaction effect is only partly offset by the revenue-recycling effect.
3. The absence of the revenue-recycling effect puts pollution quotas (as well as grandfathered pollution permits and pollution taxes with lump-sum recycling of revenues) at an efficiency disadvantage relative to pollution taxes with revenues devoted to cuts in the labor tax.
4. The marginal tax interaction effect is strictly positive, even at incremental pollution abatement (that is, even for an incremental pollution tax). The marginal tax-interaction effect at incremental abatement is a critical value for marginal environmental benefits. If the marginal benefits are below this value, any pollution abatement through a quota policy is efficiency-reducing.

Figure 1 illustrates these results. The figure shows the marginal efficiency costs of pollution abatement, at different levels of abatement, where the efficiency costs represented here are gross of the benefits from environmental improvement. The lowermost (dashed) line depicts the marginal costs of abatement in a first-best setting, that is, in the absence of pre-existing distortionary taxes. In a first-best setting, the marginal costs of abatement are the same regardless of whether a pollution tax or pollution quota is imposed. The other lines represent the marginal costs in a second-best setting with pre-existing distortionary taxes. The top line depicts the marginal costs of abatement for a pollution quota, grandfathered pollution permits, or pollution tax with lump-sum recycling of revenues. At all levels of abatement, the marginal costs of abatement under a quota are higher than in the first-best case. This is the case even at incremental abatement: the second-best marginal cost curve has a positive intercept, whereas the marginal cost of incremental abatement for the quota is zero (dashed line) in the first-best case. At any level of abatement, the tax-interaction effect is represented by the vertical distance between the top and bottom (dashed) marginal cost curve.

Figure 1. Marginal Costs of Pollution Abatement in First-and Second-Best Settings



The intercept of the top marginal cost curve represents the critical value for marginal environmental *benefits* from pollution abatement through quotas or grandfathered permits. If the marginal benefits are (always) below this value, then pollution reductions through one of these policies will always involve costs that exceed the benefits. Thus, these policies will be efficiency-reducing regardless of the level of abatement.

Some efficiency costs can be avoided through policies that raise revenues and devote them to reductions in the labor tax. The middle line in Figure 1 represents the marginal costs of abatement for a pollution tax or set of auctioned pollution permits with revenues used in this way. The revenue-recycling effect is represented by the vertical distance between the top and middle marginal cost curves. At incremental abatement, the revenue-recycling effect fully offsets the tax-interaction effect; hence, the marginal cost of abatement is zero at incremental abatement (as in the first-best case). However, for larger amounts of abatement, the revenue-recycling effect only partly offsets the tax-interaction effect (for the reasons given in subsection B above), and thus the costs of abatement exceed the costs of comparable abatement in a first-best setting.

III. Interpretations, Qualifications, and Extensions

A. Can Pollution Taxes Deliver a “Double Dividend?”

In recent years there has been considerable debate about the possibilities for “green tax reform,” that is, the substitution of taxes on pollution for ordinary, distortionary taxes. A general argument for such reform is that it makes sense to concentrate taxes on “bads” like pollution rather than “goods” like labor effort or capital formation (saving and investment). To buttress the case for green tax reform, some analysts have argued that the revenue-neutral swap of pollution taxes for ordinary taxes will produce a “double dividend:” not only (1) improve the quality of the environment but also (2) reduce certain costs of the tax system. This argument has occupied a

prominent place in the debate about carbon taxes, as mentioned in the introduction. Few analysts deny the first dividend; it is the second dividend that generates controversy.

Can environmental taxes generate the second dividend? Different policy analysts have meant different things by this dividend, and this has led to confusion. Goulder (1995a) distinguishes a “strong” and “weak” version of the double dividend claim, as follows. Let $C(\tau_E, \Delta\tau_L)$ refer to the gross cost of a revenue-neutral policy involving a new environmental tax τ_E that finances the change (reduction) $\Delta\tau_L$ in pre-existing distortionary taxes.¹⁷ Let $C(\tau_E, \Delta T)$ denote the gross cost of a revenue-neutral policy in which a new environmental tax τ_E finances the lump-sum reduction in taxes, ΔT . The weak double dividend claim is:

$$C(\tau_E, \Delta\tau_L) < C(\tau_E, \Delta T)$$

The above expression asserts that a reform in which the environmental tax’s revenues are recycled through cuts in the rates of distortionary tax involves lower gross costs than a policy in which the environmental tax’s revenues are returned lump-sum. This weak double-dividend claim is easy to justify: environmental taxes, with revenues devoted to cuts in distortionary taxes, do indeed lower the costs of the tax system *relative to what the costs would be if the revenues were returned lump-sum*. As shown in Goulder (1995a), the weak double-dividend claim is upheld so long as the tax τ_L is appropriately labeled as distortionary. That is, the weak claim is upheld if and only if the tax τ_L has a positive marginal excess burden.

In terms of Figure 1, the weak double-dividend claim is verified by the fact that the marginal cost curve for the pollution tax with lump-sum revenue-replacement lies above the curve for the pollution tax accompanied by cuts

¹⁷ In keeping with the analytical model of Section II, we use the subscript “L” to refer to the distortionary factor tax. The points raised here apply to economies in which there are several distortionary taxes, including taxes on capital as well as labor.

in the distortionary tax. In essence, the weak double-dividend claim amounts to the assertion that, in terms of efficiency, it pays to take advantage of the revenue-recycling effect. Thus it is closely related to the notion that pollution taxes that finance cuts in distortionary taxes are preferable on efficiency grounds to pollution quotas or grandfathered tradeable permits.

The stronger double-dividend claim is

$$C(\tau_E, \Delta\tau_L) \leq 0$$

that is, the revenue-neutral swap of an environmental tax for existing distortionary taxes involves zero or negative gross costs. This is equivalent to asserting that the gross distortionary cost directly attributable to the environmental tax is smaller than the avoided gross distortionary cost stemming from the environmental-tax-financed cut in the distortionary tax. If this strong double-dividend claim held for a carbon tax, then, as noted in the introduction, the tax would be justified on efficiency grounds so long as the environment-related gross *benefits* from the policy were non-negative.

Is the stronger claim justified? Figure 1 sheds light on the answer. For the strong claim to be valid, the marginal cost curve for the pollution tax accompanied by cuts in distortionary taxes would have to lie on or below the horizontal axis. Clearly the curve does not fulfill this requirement — except at zero abatement. To support the stronger double-dividend claim, the revenue-recycling effect not only would have to fully offset the tax-interaction effect, but also would have to overcome the usual, first-best abatement costs represented by the dashed line. Thus, the simple theoretical model of Section II rejects the strong double-dividend claim. For anything but an infinitesimal amount of abatement (infinitesimal environmental tax) the gross costs of a revenue-neutral environmental tax reform are positive.

Some qualifications are in order. First, it should be kept in mind that this analysis assumes that the “dirty” good is an average substitute for leisure. If instead the dirty good were a very strong complement with leisure, then the double dividend could arise after all. Further empirical work to gauge the extent of substitutability or complementarity could shed much light.

Second, more complex theoretical models can provide more scope for the strong double-dividend claim than is offered here.¹⁸ It may be noted, in particular, that the model of Section II considered only one primary factor of production — labor. In theoretical models with both capital and labor, an environmental tax reform can produce a the second dividend under certain circumstances. Specifically, if the tax system initially is highly inefficient in the sense that one factor is overtaxed relative to the other¹⁹, and if the environmental tax reform (the combination of the tax itself and the recycling of the revenues) serves to shift the tax burden from the overtaxed to the undertaxed factor, then the reform will produce a *tax-shifting effect* that works toward a more efficient tax system. If the beneficial tax-shifting effect is large enough, it (combined with the revenue-recycling effect) can entirely compensate for usual “first-best” abatement costs and the tax-interaction effect.²⁰ Thus, under these circumstances, the strong double-dividend materializes after all.

Most empirical studies indicate that in the U.S., capital is overtaxed (in efficiency terms) relative to labor.²¹ With these initial conditions, an environmental tax reform will produce a favorable tax-shifting effect if it shifts the burden away from capital and toward labor. Bovenberg and Goulder (1997) examine two environmentally motivated, revenue-neutral tax reforms — a BTU tax applied to fossil fuels and an increase in the Federal gasoline tax — and find that the latter policy produces a tax-shifting effect that

¹⁸Bovenberg (1996), Goulder (1995a), and Bovenberg and Goulder (1998) analyze a range of complicating issues.

¹⁹In efficiency terms, one factor of production is overtaxed relative to another if the tax on this factor has a larger marginal excess burden per dollar of revenue than the tax on the other factor.

²⁰For a theoretical treatment of the tax-shifting issue, see Bovenberg and de Mooij (1994b), and Bovenberg and Goulder (1997).

²¹See, for example, Ballard, Shoven, and Whalley (1985), Fullerton and Mackie (1987), Jorgenson and Yun (1990), Lucas (1990), and Goulder and Thalmann (1993).

significantly reduces the gross costs. However, the tax-shifting effect is generally not strong enough to make the gross costs zero or negative, except under extreme values for behavioral parameters. Although the results are somewhat mixed, other simulation studies have tended to support the idea that it is difficult to generate the strong double dividend under plausible parameter values and realistic policy specifications.²²

The absence of the strong double dividend does not vitiate the case for green tax reform. It only means that the positive *sign* of the environmental benefits is not a sufficient condition for justifying such reform. If there is no (strong) double dividend, policymakers are obliged to consider the magnitudes of the environmental benefits and compare them with the (positive) gross costs. Also, the absence of a double dividend does not repudiate our intuition that it makes sense to orient the tax system, to a degree, on “bads” (polluting activities) rather than “goods” (labor and capital). *Even if the strong double-dividend claim fails, it is still the case that “Pigovian considerations” should be part of the design of an efficient tax system:* other things equal, the tax on a given good or activity should be higher, the larger the environmental externalities associated with that good or activity. Higher environmental benefits justify higher taxes on polluting activities. It is the larger environmental benefits — not the presumption of zero gross costs — that justify the greening of the tax system.

B. Significance of the Scale of Abatement for the Choice between Taxes and Quotas

The theoretical model indicated that the pollution taxes and auctioned pollution permits have an efficiency advantage over pollution quotas and grandfathered pollution permits to the extent that the former policies exploit the revenue-recycling effect. However, the size of the efficiency advantage generally declines with the amount of abatement. In fact, this advantage

²² Goulder (1995a) surveys these studies.

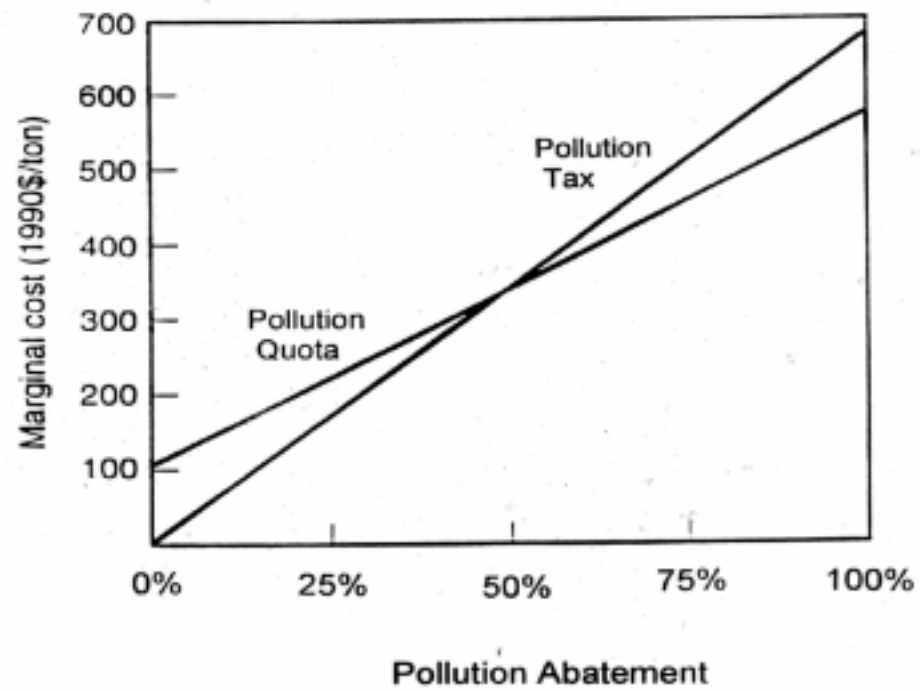
approaches zero as the extent of abatement approaches 100 percent. This is illustrated by Figure 2, which is borrowed from the GPB study. Marginal costs rise faster for the pollution tax (or auctioned pollution permit) policy. Eventually — when the extent of abatement is substantial — marginal costs under this policy exceed those for the pollution quota (or grandfathered permit) policy. Why is this so? Consider the pollution tax. Because of this policy's negative impact on labor supply and on emissions, marginal tax revenue declines as the emissions tax rate rises. This means that, with greater abatement, the ability to exploit the revenue-recycling effect diminishes. Eventually, the point is reached where, at the margin, additional abatement (via an incrementally higher pollution tax) raises no more revenue than is raised under the quota policy.²³

That is the point where the pollution tax and pollution quota marginal cost curves cross. To the right of that point, *at the margin* the tax policy is more costly than the quota policy, because at the margin it has a *negative* revenue-recycling effect (as compared with the negligible revenue-recycling effect of the quota policy). Indeed, if one pursues emissions reductions to the point of 100 percent abatement, the total costs of the two types of policies are identical. This makes sense, since at 100 percent abatement neither policy earns any revenue, and thus there is no effective difference between a tax and a quota at that point. Thus the areas under the marginal cost curves from 0 to 100 percent abatement are the same for both policies.

These results demonstrate that the relative superiority (in terms of lower cost) of policies that exploit the revenue-recycling effect diminishes with the extent of abatement. At low levels of abatement (as would be appropriate if marginal environmental *benefits* are low), these policies have a considerable cost advantage. But at high levels of abatement (as would be justified when marginal environmental benefits are high) the advantage of these policies is

²³ The quota policy does not necessarily raise zero revenue. This policy will tend to raise revenue insofar as quota rents are taxed, and will tend to lose revenue insofar as the policy causes a loss of overall real income and a reduction in the labor tax base.

Figure 2. Marginal Costs over the Entire Range of Possible Emissions Reductions



much smaller. In the limiting case of 100 percent abatement, these policies have no cost advantage.

C. Impacts of Other Environmental Policies in a Second-Best Setting

Thus far, all of the discussion in this paper has centered on pollution taxes, quotas, and permits. Recent papers by Fullerton and Metcalf (1997) and Goulder, Parry, Williams, and Burtraw (1998) examine the impacts of other policy instruments (in addition to pollution taxes and quotas) in a second-best setting.²⁴ Among the additional instruments considered in these recent papers are some “command-and-control” policies: namely, mandated technologies and performance standards.

Goulder *et al.* (1998) show that pre-existing taxes also raise the costs of the command-and-control policies relative to their costs in a first-best world. Like emissions taxes and quotas, the command-and-control policies raise production costs and lead to higher output prices. If there are prior distortionary taxes in factor markets, the higher output prices give rise to a tax-interaction effect, which implies higher costs relative to the costs in a first-best setting.

Although second-best considerations raise the costs of all instruments, they do not increase costs in the same proportion. Indeed, when the amount of pollution-abatement is incremental or “small,” pre-existing taxes especially raise the costs of non-auctioned quotas or permits, and can put non-auctioned quotas or permits at a cost-disadvantage relative to command-and-control policies. Economists have long favored market-based policies as being more cost-effective than the command-and-control alternatives. Yet in a second-best setting, certain market-based policies can be at a disadvantage. The recent studies by Fullerton and Metcalf and Goulder *et al.* indicate that the

²⁴ See also Ng (1980), who analyzed environmental subsidies in the presence of prior tax distortions.

marginal abatement costs of performance standards and technology mandates resemble those of the emissions tax in that marginal costs are zero at the first increment of abatement.²⁵ This contrasts with the strictly positive costs of initial abatement under a non-auctioned quota. Thus, for “low” amounts of abatement, a command-and-control policy can be less costly than grandfathered permits. However, it should be kept in mind that the command-and-control policies eventually involve higher costs as the amount of abatement becomes very extensive. As discussed in Goulder *et al.* (1998), this reflects the inability of these alternative instruments to provide the appropriate prices of inputs and outputs.

It is worth considering further why the marginal cost curves of these alternative instruments emerge from the origin (as in the case of the pollution tax or auctioned quota — with revenues devoted to marginal rate reductions), while the marginal cost curves of grandfathered quotas (or emissions taxes with revenues returned lump sum) do not. Since the mandated technology and performance standard do not raise revenue, it is clear that raising revenue *per se* is not necessary for the zero-marginal-cost-at-initial-abatement property to obtain. One can explain these differences in terms of whether the tax-interaction and revenue-recycling effects cancel at initial abatement. At the first incremental amount of abatement, emissions taxes (with revenues returned through marginal rate cuts) produce strictly positive tax-interaction effect that is exactly offset by the strictly negative revenue-recycling effect. Hence the marginal abatement costs are zero at initial abatement. The mandated technology and performance standard produce neither a tax-interaction effect nor a revenue-recycling effect. Hence the marginal costs

²⁵ This point was first demonstrated by Fullerton and Metcalf. This was shown for a “technology restriction” policy, which was a constraint on the ratio of labor input to emissions. In their model, this is functionally equivalent to a policy involving a constraint on the ratio of emissions to output.

of abatement are again zero at initial abatement.²⁶ In contrast, under grandfathered quotas there is a strictly positive tax-interaction effect and no offsetting revenue-recycling effect. Hence marginal costs are strictly positive. Thus, the tax-interaction and revenue-recycling effects can explain one way to explain why marginal costs start out strictly positive under non-auctioned permits or quotas, and start out at zero under the other policies.

These differences at initial abatement can also be linked to the presence or absence of a lump-sum transfer. The government effectuates a lump-sum transfer to individuals when it introduces a pollution tax and returns the revenues lump-sum, when it implements a pollution quota (thus generating quota rents that are not entirely taxed away), or when it introduces a pollution tax and recycles the revenues through cuts in the marginal tax rate on a perfectly inelastically supplied factor of production.²⁷ In a second-best world, such transfers involve an efficiency cost because they must ultimately be financed through distortionary taxes. In contrast, under the pollution tax or fuels tax (with revenues financing cuts in prior taxes), or under the mandated technology or performance standard, there is no such transfer. Thus the presence or absence of a positive intercept of the marginal cost function corresponds to the presence or absence of this lump-sum transfer.²⁸

²⁶ More precisely, the technology mandate produces two tax-interaction effects and two revenue-recycling effects. As indicated by Fullerton and Metcalf, the mandated technology is equivalent to the combination of a subsidy to the use of the clean input and a tax on emissions. The subsidy and tax components respectively account for negative (in efficiency terms) and positive revenue-recycling effects, which cancel out, and positive and negative tax-interaction effects, which also cancel out (at the first unit of abatement).

²⁷ This last case is examined by Bovenberg and de Mooij (1996) and Williams (1998).

²⁸ Fullerton and Metcalf (1997) point out that pollution regulation through grandfathered permits creates scarcity rents that remain in private (that is, the regulated firm's) hands, and indicate that this accounts for the fact that the marginal costs of incremental abatement are strictly positive. The creation of scarcity rents is an example of the government's bringing about a lump-sum transfer to the private sector.

IV. Some Numerical Results

Thus far we have only considered results from analytical models. Analytical tractability comes at a price in that it necessitates the use of fairly simple models. In this section we briefly display results from some numerical models.²⁹

First we present some results that pertain to the double-dividend issue. Here we display and briefly interpret results from the disaggregated computable general equilibrium model employed in Bovenberg and Goulder (1997). We will only sketch the results here; the reader is referred to Bovenberg-Goulder article for details. In this discussion we also present a sampling of results from other numerical models.

Next we display numerical results indicating how pre-existing taxes affect the choice between auctioned and grandfathered emissions permits, in the context of sulfur dioxide (SO₂) and carbon dioxide (CO₂) emissions reductions in the U.S.

A. Numerical Explorations of the Double-Dividend Issue

1. Results from Bovenberg-Goulder (1997)

Here we examine simulations in which a fossil fuel Btu tax or a consumer gasoline tax increase is implemented in revenue-neutral fashion, with the revenues devoted to reductions in the income tax. An important item to keep in mind when interpreting the results is the relative taxation of capital and labor. In the baseline, or reference equilibrium (and under central values for parameters), the marginal excess burden (MEB) of capital taxes is .43, while the MEB of labor taxes is .31. This means that the tax-shifting effect

²⁹ Real-world environmental taxes and other regulations involve “large,” as opposed to incremental, changes in the level of pollution. Numerical simulation is usually necessary to evaluate the efficiency implications of these changes.

(see III.A above) works in favor of the second dividend when policies shift the burden of taxation from (overtaxed) capital to (undertaxed) labor. In this regard, note that while the Btu tax tends to fall more or less evenly on capital and labor, the gasoline tax tends to fall mainly on labor (by virtue of its being akin to a consumption tax). Hence the gasoline tax has more potential for tax-shifting that supports the second dividend.

Figure 3 shows results when these taxes are introduced with *lump-sum* replacement of the revenues. Figure 3a shows that in the short term, the environmental (Btu and gas) taxes entail a greater GDP sacrifice than the personal income tax. Figure 3b shows that the gasoline tax has a much smaller investment cost than does the Btu tax or income tax. This reflects the fact that the gasoline tax tends to ease the tax burden on capital.

Table 1 shows the effects of these policies on factor prices and quantities. It indicates that the combination of gasoline tax increase and reduction in personal income tax reduces capital's tax burden and raises labor's. In contrast, the combination of Btu tax and cut in personal income tax does not significantly alter the relative taxation of capital and labor. Thus, the revenue-neutral policy involving the gasoline tax produces a more significant tax-shifting effect.

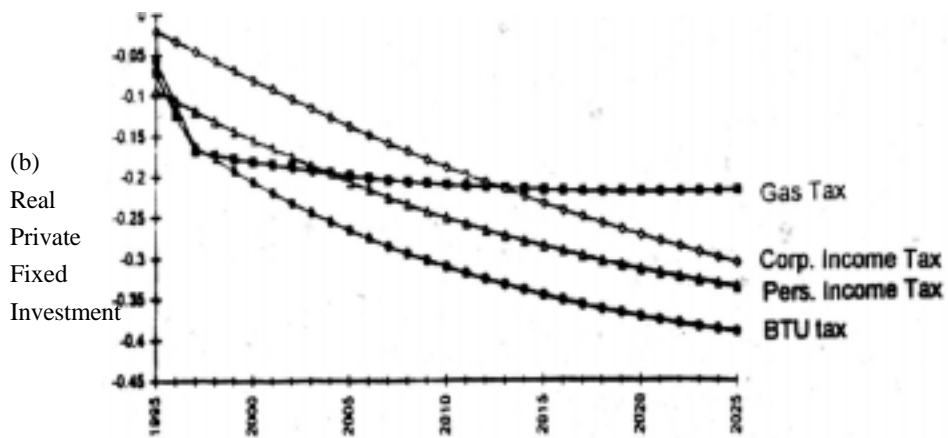
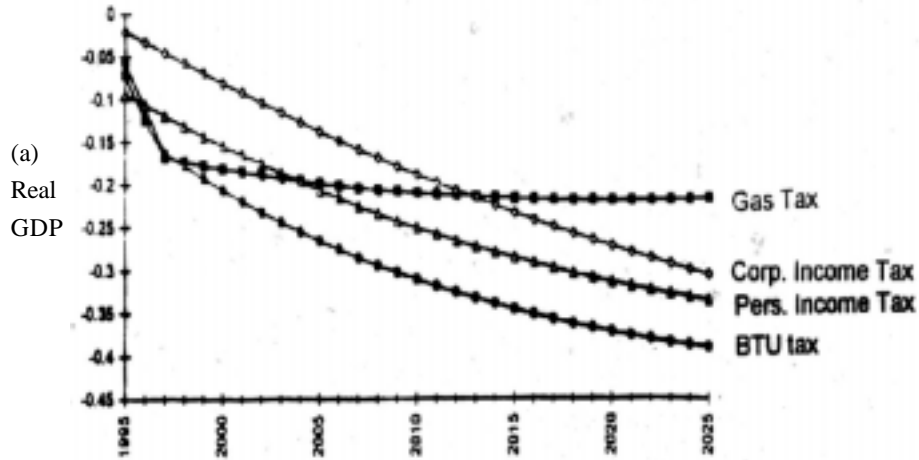
Table 2 shows welfare effects. These are the monetary equivalent (using the equivalent variation) of the change in utility associated with the policy change. These welfare measures disregard welfare impacts associated with the changes in environmental quality; they refer only to the cost side of the benefit-cost ledger.

Comparing the left and right columns indicates the importance of the revenue-recycling effect; that is, of returning revenues through cuts in marginal tax rates instead of through lump-sum tax cuts. The welfare costs of the revenue-neutral reforms are significantly higher when revenues are returned in lump-sum fashion.

Concentrate now on the right column, which displays results from revenue-neutral policies in which the environmental tax revenues finance reductions in the personal tax. There are two main results from this column. First, the

Figure 3. Aggregate of Energy and Income Tax Policies

Revenue Replacement via Lump-Sun Tax Cuts
(percentage changes from reference case)



**Table 1. Impacts of Taxes on Factor Prices and Supplies
(Percentage Changes from Baseline)**

	Years after Policy Introduction			
	1	2	5	30
<i>“Single Tax” Policies:</i>				
BTU Tax lump-sum replacement				
<i>W</i>	-0.250	-0.390	-0.446	-0.655
<i>r</i>	-0.083	-0.239	-0.179	-0.084
<i>L</i>	-0.124	-0.140	-0.121	-0.049
<i>K</i>	-0.017	-0.035	-0.092	-0.364
Gasoline tax increase. lump-sum replacement				
<i>W</i>	-0.722	-0.069	-0.058	-0.983
<i>r</i>	0.095	-0.007	-0.027	-0.005
<i>L</i>	-0.265	.0335	-0.331	-0.298
<i>K</i>	-0.011	-0.019	-0.031	-0.069
Personal tax increase lum-sum replacement				
<i>W</i>	-0.333	-0.347	-0.404	-0.655
<i>r</i>	-0.104	-0.108	-0.105	-0.053
<i>L</i>	-0.015	-0.274	-0.265	.0212
<i>K</i>	-0.015	-0.030	-.0072	-0.313
<i>Substitution of Environmental Tax for Personal Tax:</i>				
BTU tax, personal tax replacement				
<i>W</i>	0.083	-0.042	-0.042	0.014
<i>r</i>	0.031	-0.125	-0.074	-0.053
<i>L</i>	0.157	0.139	0.149	0.163
<i>K</i>	-0.001	-0.005	-0.019	-0.037
Gasoline tax increase, personal tax replacement				
<i>W</i>	-0.375	-0.694	-0.571	-0.307
<i>r</i>	0.216	0.111	0.076	0.057
<i>L</i>	0.013	-0.057	-0.061	-0.084
<i>K</i>	0.004	0.012	0.041	0.252

Note: *W*, *r*, *L*, and *K* respectively, refer to the after tax real wage, after tax real rate of return, aggregate real labor supply, and aggregate real capital stock.

Table 2. Welfare Impacts

	Welfare Cost per Dollar of Revenue	
	Lump Sum Tax Replacement	Personal X Income Tax Replacement
BTU tax	0.656	0.318
Consumer level gasoline tax increase	0.594	2.253
Personal income tax increase	0.379	--
Corporate income tax increase	0.438	0.093

second dividend does not arise: the gross welfare costs (i.e., the costs before netting out the environmental benefits) are positive. Second, the welfare cost is lower for the gasoline tax reform, despite the narrower base of the gasoline tax. This reflects the tax-shifting effect: as Table 1 indicated, under the gasoline tax reform the tax burden is shifted from capital to labor, which tends to reduce the gross costs. However, the tax-shifting effect is not strong enough to undo the cost associated with the tax-interaction effect.

Is it possible to make the tax-shifting effect large enough to give the second dividend? Yes. The tax-shifting effect will be stronger to the extent that (1) the initial inefficiencies in the relative taxation of capital and labor are large, and (2) the policy shifts the burden from the overtaxed to the undertaxed factor. To enhance the first condition, we have performed simulations with very elastic capital supply assumptions. Specifically, we assume that the elasticity of substitution in consumption (which affects the household's interest elasticity of saving) is "high" relative to most estimates. To enhance the second condition, we consider a policy in which a gasoline tax is introduced and all the revenues from this tax are recycled through cuts in capital taxes only. This combination produces a large enough tax-shifting effect to yield the second dividend if the intertemporal elasticity of substitution is 1.8 or more. Although this shows that the second dividend can arise, producing this dividend seems to require implausibly high values for the

Table 3. Numerical Assessments of Welfare Impacts of Revenue-Neutral Environmental Tax Reforms

Model	Reference	Country	Type of Environmental Tax	Method of Revenue Replacement	Welfare Effect
DRI	Shackleton et al. (1996)	U. S.	Phased-in Carbon Tax ^a	Personal Tax Cut	-0.39 ^b
Goulder	Coulder (1995b)	U. S.	\$ 35/ton Carbon Tax	Personal Tax Cut	-0.33 ^c
«	Goulder (1994)	U.S.	Fossil Fuel Btu Tax	Personal Tax Cut	-0.28 ^c
Jorgenson-Wilcoxon	Shackleton et. al (1996)	U.S.	Phased-in Carbon Tax ^a	Capital Tax Cut	0.19 ^d
LINK	Shackleton et. al (1996)	U.S.	Phased-in Carbon Tax ^a	Personal tax Cut	-0.51 ^b
MSE...					
Proost-Regemorter	Proost and Regemorter (1995)	Belgium	Hybrid of Carbon and Energy Tax	Payroll (Social Security) Tax Cut	-3.45 ^d
Shah-Larsen	ShaH AND Larsen (1992)	U.S.	\$ 10/ton Carbon Tax	Personal Tax Cut	-1049. ^e
«	«	India	«	«	-129.
«	«	Indonesia	«	«	-4.
«	«	Japan	«	«	-269.
«	«	Pakistan	«	«	-23.

Notes: (a) Beginning at \$ 15/ton in 1990 (period 1), growing at five percent annually to \$ 39.80 per ton in 2010 (period 21), and remaining at that level thereafter. (b) Percentage change in the present value of consumption; the model does not allow for utility-based welfare measures. (c) Welfare cost per dollar of tax revenue, as measured by the equivalent variation. (d) Equivalent variation as a percentage of benchmark private wealth. (e) Compensating variation in levels (millions of U.S. dollars).

intertemporal elasticity of substitution (most estimates are between 0 and unity³⁰).

2. Results from a Sampling of Other Models

Table 3 summarizes results from numerical studies of a revenue-neutral carbon tax policy. The table presents results from seven numerical models. These are the Goulder and Jorgenson-Wilcoxon intertemporal general equilibrium models of the U.S., the Proost-Regemorter general equilibrium model of Belgium, the DRI and LINK econometric macroeconomic models of the U.S., and the Shah-Larsen partial equilibrium model, which has been applied to five countries, including the U.S.³¹ The results in Table 3 are for the revenue-neutral combination of an environmental tax (usually a carbon tax) and reduction in the personal income tax, except in cases where this combination was not available.

All welfare changes abstract from changes in welfare associated with improvements in environmental quality (reductions in greenhouse gas emissions). Thus they correspond to the gross cost concept discussed above. In the Goulder, Jorgenson-Wilcoxon, and Proost-Regemorter models, welfare changes are reported in terms of the equivalent variation; in the Shah-Larsen

³⁰ Using time-series data, Hall (1988) estimates that this elasticity is below 0.2. A cross-section analysis by Lawrence (1991) generates a central estimate of 1.1. Estimates from time-series tend to be lower than those from cross-section analyses.

³¹ For a more detailed description of these models, see Goulder (1995b), Jorgenson and Wilcoxon (1990, 1996), Shackleton *et al.* (1996), Proost and Regemorter (1995), and Shah and Larsen (1992). The Shah-Larsen model is the simplest of the models, in part because it takes pre-tax factor prices as given. Despite its simplicity, the model addresses interactions between commodity and factor markets and thus incorporates some of the major efficiency connections discussed earlier.

model, the changes are based on the compensating variation.³² In the DRI and LINK macroeconomic models, the percentage change in aggregate real consumption substitutes for a utility-based welfare measure.³³

In most cases, the revenue-neutral green tax swap implies a reduction in welfare, that is, entails positive gross costs. This militates against the double dividend claim. Results from the Jorgenson-Wilcoxon model, however, support the double dividend notion. Relatively high interest elasticities of savings (a high capital supply elasticity) and the assumption of perfect capital mobility across sectors may partially explain this result, at least in the case where revenues from the carbon tax are devoted to cuts in marginal taxes on capital. These assumptions imply large marginal excess burdens from taxes on capital, considerably larger than the MEBs from labor taxes. As indicated above, if the MEB on capital significantly exceeds that on labor, and the environmental reform shifts the tax burden on to labor, the double dividend can arise. Thus, the large MEBs from capital taxes help explain why, in the Jorgenson-Wilcoxon model, a revenue-neutral combination of carbon tax and reduction in capital taxes involves negative gross costs, that is, produces a double dividend. Identifying the sources of differences in results across models is difficult, in large part because of the lack of relevant information on simulation outcomes and parameters. Relatively few studies have performed the type of analysis that exposes the channels underlying the overall impacts. There is a need for more systematic sensitivity analysis, as well as closer investigations of how structural aspects of tax policies (type of tax base, narrowness of tax base, uniformity of tax rates, etc.) influence the

³² The equivalent variation is the lump-sum change in wealth which, under the “business-as-usual” or base case, would leave the household as well off as in the policy-change case. Thus a positive equivalent variation indicates that the policy is welfare-improving. The compensating variation is the lump-sum change in wealth that, in the policy-change scenario, would cause the household to be as well off as in the base case. In reporting the Shah-Larsen results we adopt the convention of multiplying the compensating variation by -1, so that a positive number in the table signifies a welfare improvement here as well.

³³ The demand functions in these models are not derived from an explicit utility function. Hence they do not yield utility-based measures.

outcomes. In addition, key behavioural parameters need to be reported. Serious attention to these issues will help explain differences in results and, one hopes, lead to a greater consensus on likely policy impacts.

B. Pre-Existing Taxes and the Choice between Auctioned and Non-Auctioned Pollution Permits

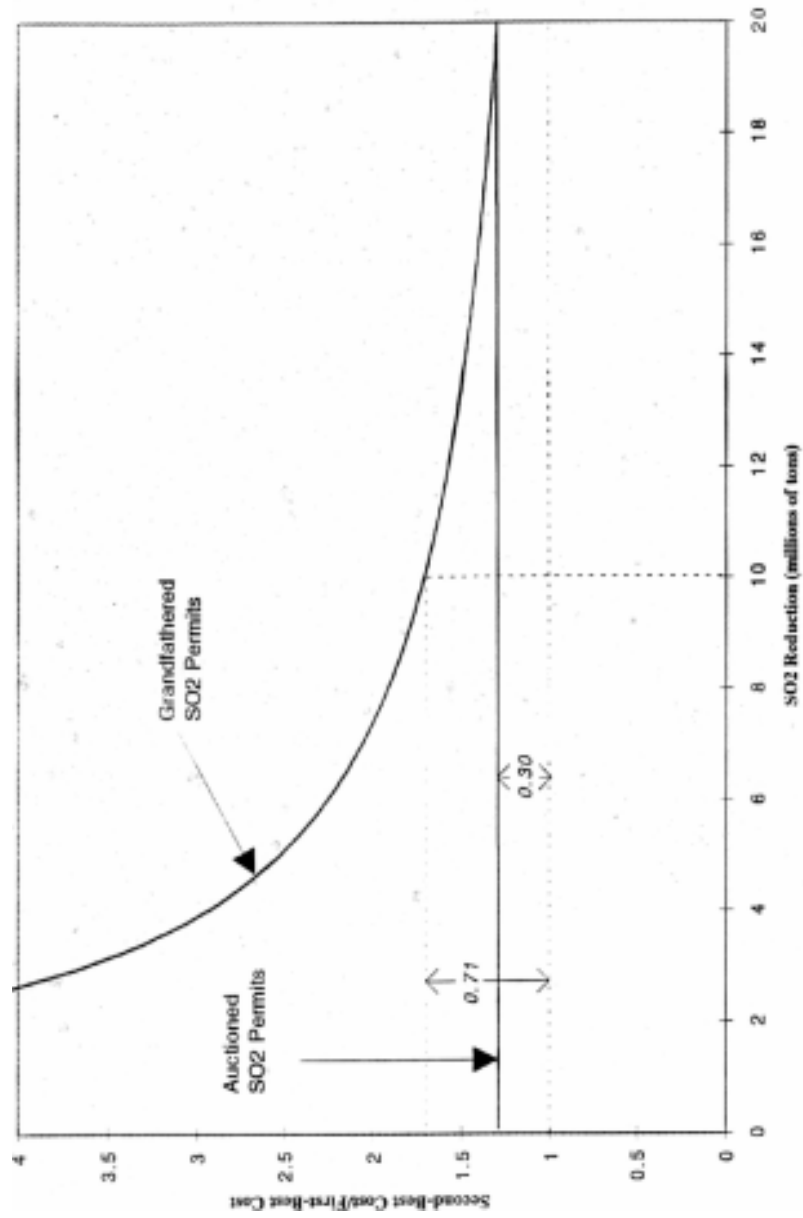
Here we display numerical results that bear on the importance of pre-existing taxes for the choice between auctioned and non-auctioned (or grandfathered) pollution permits. As the discussion in Section II indicates, these results display the significance of the revenue-recycling effect. Thus the principles here are somewhat broader than the choice between auctioned or grandfathered permits. The results for auctioned permits also would apply to emissions taxes that exploit the revenue-recycling effect by using the revenues to finance cuts in marginal rates of pre-existing factor taxes. Likewise, the results for non-auctioned permits apply to emissions taxes that fail to exploit the revenue-recycling effect by returning the revenues in a lump-sum fashion.

1. Sulfur Dioxide Abatement

The GPB study includes an assessment of the costs of reducing emissions of sulfur dioxide (SO_2) from U.S. coal-fired electric power plants. Provisions of the 1990 Clean Air Act Amendments call for such reductions and introduce a system of grandfathered SO_2 emissions permits to achieve them.

Two questions arise. First, how much higher are the costs of reducing SO_2 emissions as a result of pre-existing taxes? And how much of the increase in abatement costs could be avoided if the reductions were achieved through a policy that auctioned the permits (or imposed an SO_2 tax) and exploited the revenue-recycling effect, rather than through a policy that grandfathered the permits? Figure 4 gives GPB's best estimates of the answers to these questions. The two solid lines in the figure are the ratios of total costs in a second-best setting (with a positive pre-existing tax rate on labor equal to 0.4) to total costs in a first-best setting (with no pre-existing tax on labor).

Figure 4. Ratio of Second-Best to First-Best Total Costs, SO₂ Case

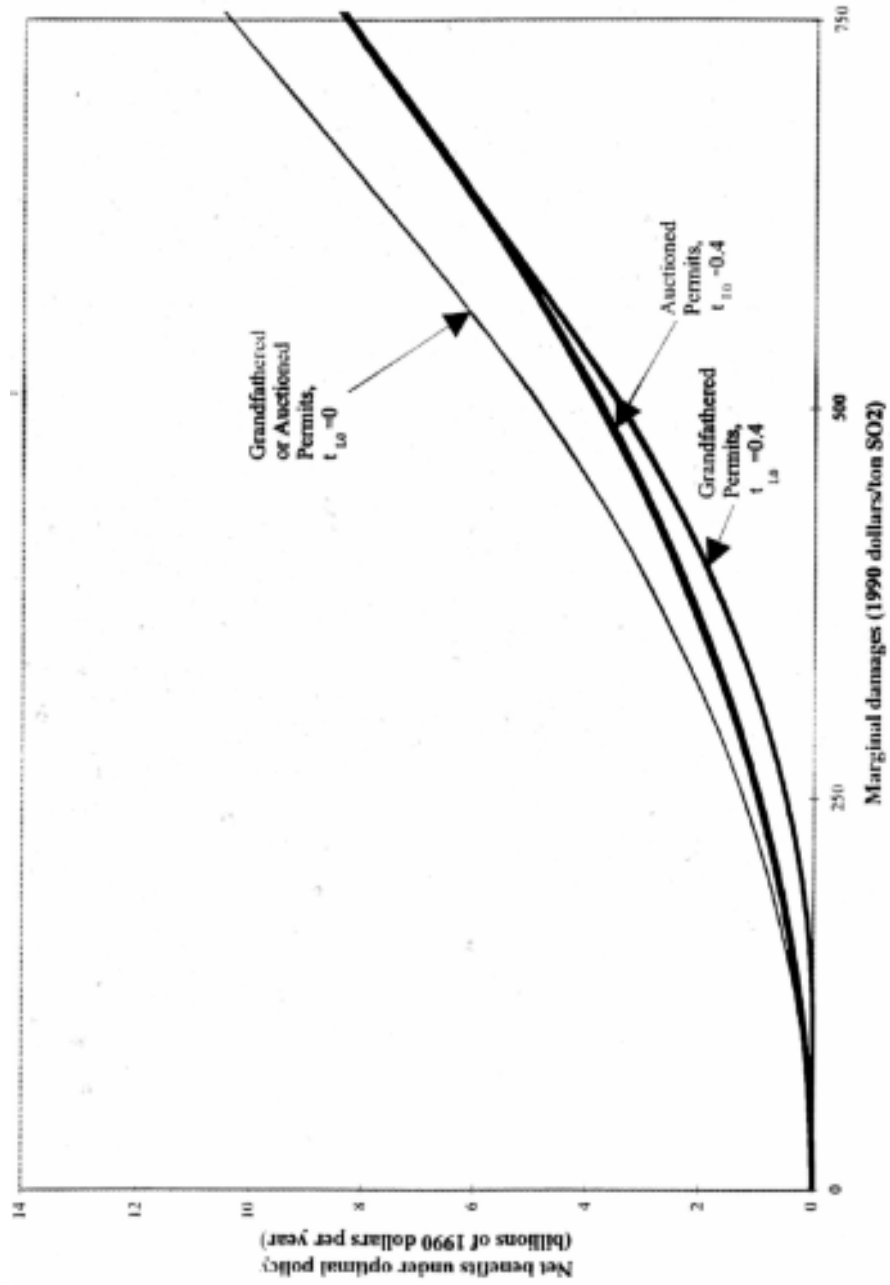


In the case of auctioned permits (or pollution taxes), the line is almost perfectly horizontal: this ratio is approximately constant throughout the entire range of possible emissions reductions (0 to 20 million tons). Second-best considerations raise the costs of auctioned permits by about 30 percent, regardless of the extent of emissions abatement. For the actual policy of grandfathered emissions permits, the ratio of total cost is very sensitive to the extent of abatement. Under this policy the ratio begins at infinity, in keeping with the fact that the intercept of the *marginal* cost function is positive for this policy in a second-best world and zero in first-best world. As the level of abatement approaches 100 percent, the ratio of total costs approaches the ratio for auctioned permits. This is in keeping with the point made in Section III that the efficiency disadvantage of policies that forgo the revenue-recycling effect disappears at 100 percent abatement.

The 1990 Clean Air Act Amendments call for a 10-million-ton (or approximately 50 percent) reduction in SO₂ emissions. There may be significant distributional or political objectives that are served by grandfathering, but Figure 4's results indicate that they come at a high price in terms of the social cost of abatement. At 10 million tons of abatement, annual total costs under the actual policy are estimated to be 71 percent (or \$907 million) higher than they would be in a first-best world. As indicated in this figure, over half of this extra cost could be avoided by auctioning the permits or employing an SO₂ tax. The difference in cost between the two types of policy is \$533 million.³⁴ These results indicate that pre-existing

³⁴ The costs of a 10-million-ton reduction are \$2182 and \$1649 million under the grandfathering and auctioning of emissions allowances, respectively. Although this paper points out the efficiency drawbacks of the grandfathering element of SO₂ emissions regulation under the 1990 Clean Air Act Amendments, it is not intended to be a wholesale critique of this legislation. We would note that the 1990 legislation achieved major reforms in environmental regulation by introducing a flexible, incentive-based approach to regulation in the form of emissions allowance trading. This approach has a number of theoretical advantages over the traditional, less flexible methods (see, for example, Tietenberg [1985]), and empirical studies already indicate that this approach will yield a dramatic reduction in overall compliance costs, compared to conventional approaches (see, for example, Burtraw [1996], and Ellerman and Montero [1996]).

Figure 5. Net Welfare Gain from the Optimal Level of SO₂ Regulation



taxes and the presence or absence of revenue-recycling have a very substantial impact on the costs of environmental policies.

Figure 5 brings in the benefit side in considering the overall efficiency gains from SO₂ abatement. The overall gains obviously depend on the marginal benefits from SO₂ reductions, and these are highly uncertain. Most estimates are in the range of \$100-600 per ton, but some recent estimates are as high as \$1000 per ton. Figure 5 displays the net efficiency gains as a function of different values for the marginal benefits, ranging from zero to \$1000 per ton.³⁵ The figure shows the efficiency gains that result under optimal levels of abatement, that is, abatement levels that equate marginal benefits with marginal costs. For low and intermediate values of the marginal benefits, the efficiency gains are considerably larger when SO₂ permits are auctioned than when they are grandfathered, in keeping with the lower marginal costs of abatement in the former case. Indeed, net gains under grandfathered permits are zero if marginal benefits are below \$104 per ton, because in this circumstance the optimal policy is not to regulate SO₂; that is, the optimal reduction in SO₂ is zero. For very high values of the marginal benefits, there is less difference in the net efficiency gains. In fact the net efficiency gains are identical for marginal benefits greater than or equal to about \$680 per ton. When marginal benefits beyond this level, the optimal policy is to eliminate SO₂ emissions entirely. At this point it makes no difference whether permits are grandfathered or auctioned, since no permits are actually provided and thus no revenue can be raised in either case.

2. Carbon Dioxide Abatement

Recent work by Parry, Williams, and Goulder (1998) examines these issues in the context of carbon dioxide (CO₂) emissions abatement in the U.S. Figures 6 and 7, based on results from this study, provide for CO₂ abatement

³⁵ The marginal benefits are assumed to be constant, that is, independent of the level of abatement.

Figure 6. Ratio of Second-Best to First-Best Total Costs, SO₂ Case

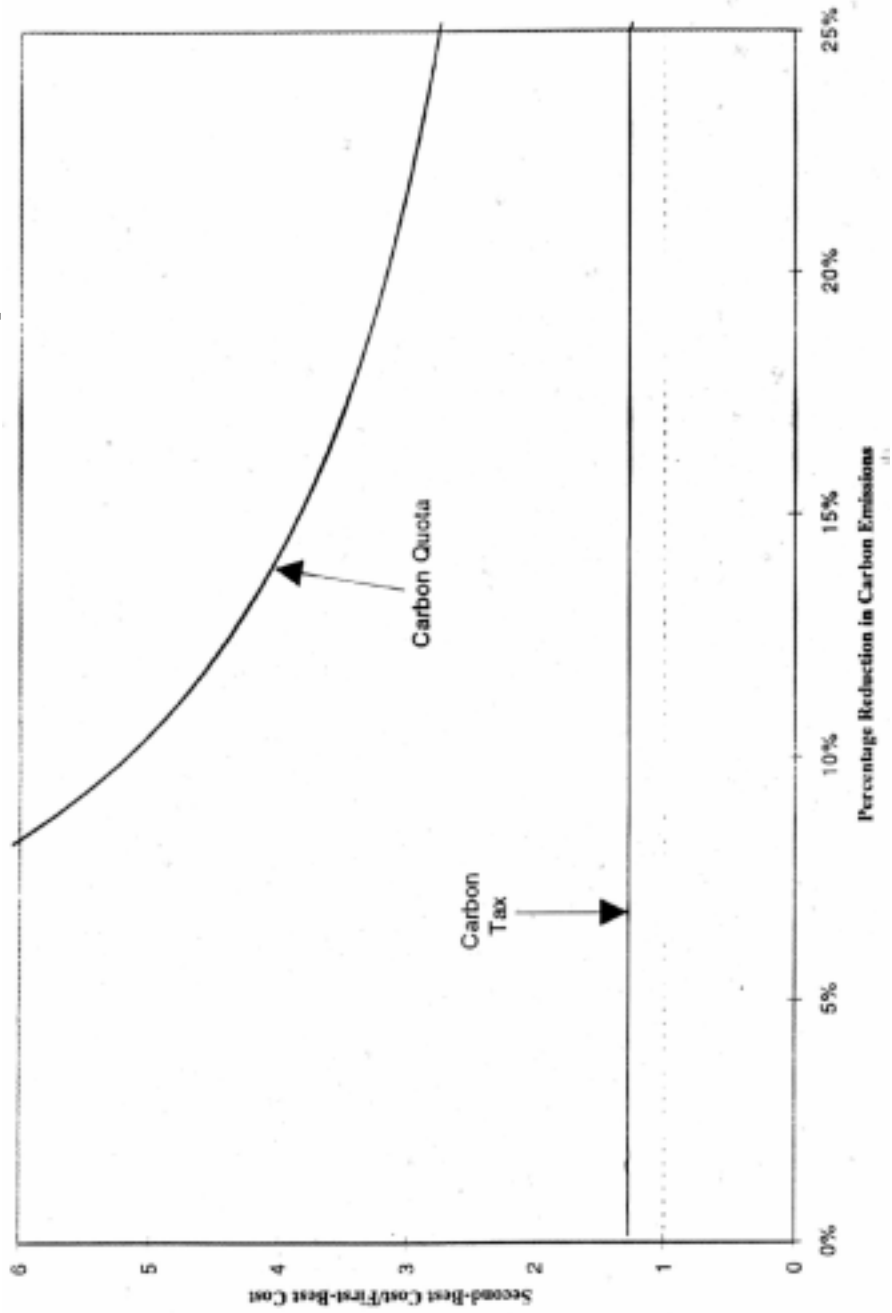
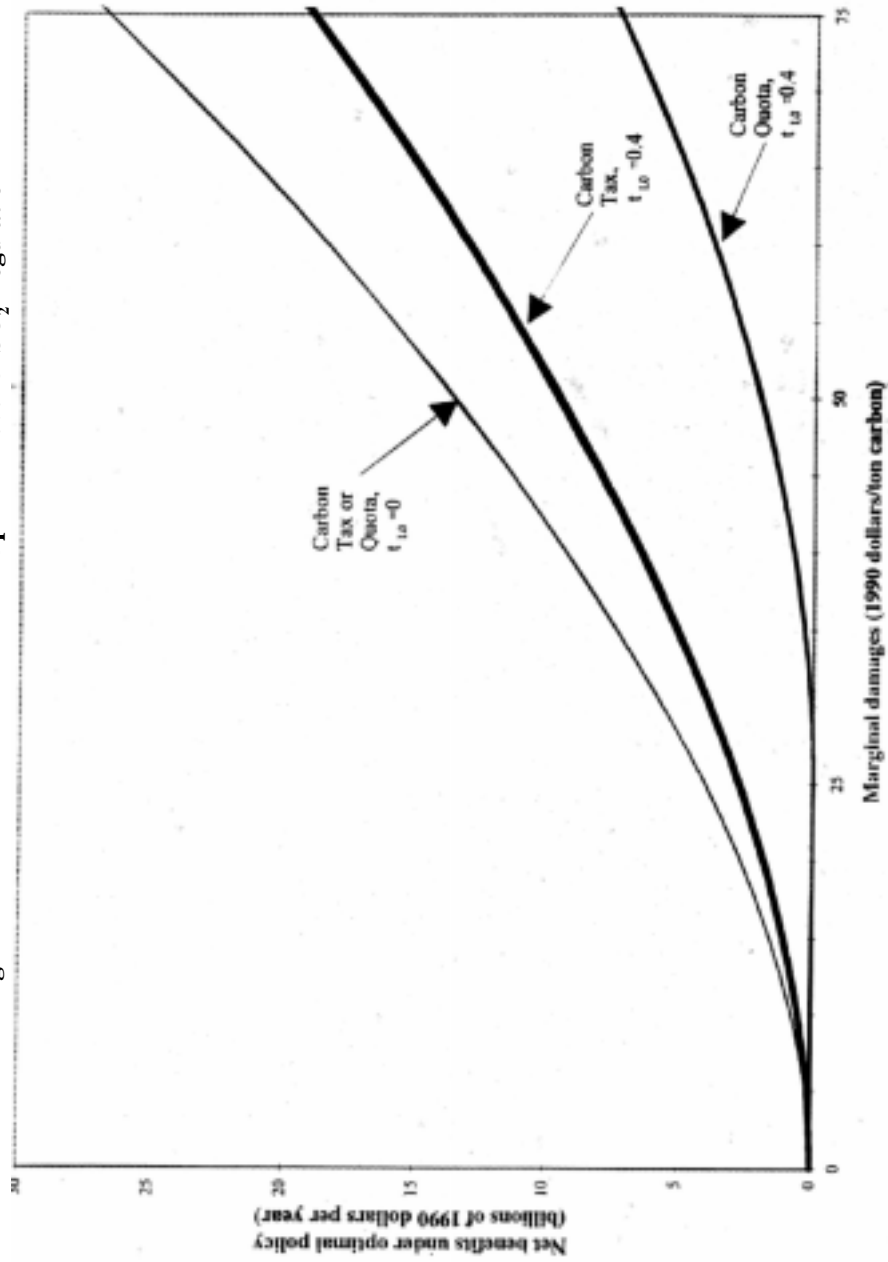


Figure 7. Net Welfare Gain from the Optimal Level of SO₂ Regulation



policies the same sort of information as was displayed for SO₂ policies in figures 4 and 5.

Figure 6 presents the ratio of second-best ($\tau_L = .4$) and first-best ($\tau_L = 0$) total costs, under a carbon (CO₂) tax and a carbon (CO₂) quota.³⁶ The carbon tax policy exploits the revenue-recycling effect: revenues from the tax are devoted to cuts in the pre-existing distortionary (labor) tax. The results are qualitatively similar to the results that were shown in Figure 4. For the carbon tax, the ratio of total costs is virtually unaffected by the extent of carbon emissions abatement. For the carbon quota, in contrast, the ratio of total costs is highly sensitive to the amount of abatement, for the same reasons as were discussed earlier.

Figure 7 shows Parry, Williams, and Goulder's best estimates for net efficiency gains from carbon abatement policies, for a range of values for the marginal benefits from CO₂ abatement. Efficiency gains are considerably larger under the carbon tax than under the carbon quota. In fact, efficiency gains are zero (the optimal amount of abatement is zero) if marginal benefits are below \$25 per ton. This reflects the fact that the (gross) marginal costs of CO₂ abatement begin at \$25 per ton under the quota policy. Thus, any emissions abatement by way of this type of policy will be efficiency-reducing if the marginal benefits are below this value. Most estimates of the marginal environmental benefits from carbon abatement obtain values below \$25 per ton.³⁷ Thus, these results suggest that any carbon abatement by way of a

³⁶ The tax and quota policies actually would be oriented toward the use of carbon-based fuels (oil, coal, and natural gas) rather than emissions of CO₂ itself. Emissions from the combustion of these fuels are strictly proportional to carbon content, so that taxing or regulating the use of these fuels is virtually equivalent to taxing or regulating CO₂ emissions. A complication is posed by non-combustion or feedstock uses of these fuels. In the U.S., such uses represent a very small share (less than four percent) of total use.

³⁷ See, for example, Nordhaus (1991), Peck and Teisberg (1993), and Fankhauser (1994).

quota (or freely offered set of carbon permits) will be efficiency reducing!³⁸

Thus, in the context of regulating SO₂ and CO₂ emissions, second-best interactions have a very substantial effect on the gross costs and net efficiency gains. Pre-existing taxes significantly raise the costs of achieving emissions reductions relative to the costs in a first-best setting. And they put policies involving emissions quotas or grandfathered permits policies at a very significant cost disadvantage relative to policies that raise revenue and finance cuts in pre-existing taxes. Second-best interactions have first-order consequences.

V. Conclusions

This paper examines the significance of pre-existing factor taxes for various environmental policies. It indicates that, under plausible assumptions, prior factor-market distortions raise the costs of revenue-neutral environmental policies, despite the potential to use the revenues from environmental taxes to finance cuts in the marginal rates of pre-existing factor taxes. It also shows that prior factor taxes amplify the costs of other environmental policies, including pollution quotas and tradeable pollution permits, relative to what the costs would be in a first-best world.

Two effects underlie these results. The *tax-interaction effect* is the adverse impact in factor markets arising from reductions in after-tax returns to factors (labor) brought about by environmental regulation. In a world with prior taxes on factors, this effect leads to significantly higher costs of regulation relative to what would apply in a first-best world with no pre-existing taxes. By generating revenues and using them to reduce pre-existing tax rates, pollution taxes and auctioned pollution permits exploit a *revenue-recycling*

³⁸ Several studies suggest that the marginal climate-related damages increase with CO₂ concentrations. If this is the case, and if CO₂ concentrations increase through time, then marginal damages from CO₂ emissions (or marginal benefits from CO₂ emissions abatement) will increase over time. Under such circumstances the prospects for efficiency gains under a quota policy improve with time.

effect that offsets some of the tax-interaction effect. In contrast, pollution quotas and grandfathered permits enjoy no such offset. Thus the costs of achieving given reductions in pollution are higher under these latter policies.

Even when they take advantage of the revenue-recycling effect, pollution abatement policies through pollution taxes or auctioned permits generally entail positive gross costs. If the good responsible for pollution emissions is an average substitute for leisure, the revenue-recycling effect only partly offsets the gross costs attributable to the tax-interaction effect. This implies that pollution-abatement through these policies is more costly in a second-best setting than it would be in a first-best world, and that the double dividend claim (in its strong form) is not upheld.

The interactions with factor markets affect the choice among alternative policy instruments. In particular, they put pollution quotas and grandfathered pollution permits at a serious efficiency disadvantage relative to revenue-raising policies whose revenues finance reductions in the marginal rates of existing taxes. Indeed, if the marginal environmental benefits from pollution reductions are below a certain threshold value, then *any* level of pollution abatement through quotas or grandfathered permits is efficiency-reducing. These results emerge from simple analytical models and are confirmed by numerical investigations in specific regulatory contexts.

In recognizing the efficiency advantages of these pollution-tax and auctioned-permit policies over policies involving pollution quotas or grandfathered permits, one should not lose sight of related equity issues. The decision whether to exploit the revenue-recycling effect fundamentally affects the distribution of wealth between taxpayers, on the one hand, and owners and employees of polluting firms, on the other. Clearly, there are important equity issues associated with the differences in distribution. The second-best considerations raised in this paper do not reduce the importance of the equity issues, but at the same time they indicate that the efficiency costs of forgoing the redistribution toward taxpayers are greater than what would be suggested by a first-best analysis.

The tax-interaction effect is relevant to government regulation outside

the environmental area. To the extent that government regulations of international trade or agricultural production raise the costs of output and thereby reduce real factor returns, these regulations exacerbate the labor market distortions from pre-existing taxes and thus involve higher social costs than would be indicated by partial equilibrium analyses.³⁹

References

- Ballard, Charles, L., John B. Shoven, and John Whalley, 1985. "General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the U.S." *American Economic Review* 75(1):128-38.
- Bovenberg, A. Lans, 1996. "Environmental Policy, Distortionary Labor Taxation, and Employment: Pollution Taxes and the Double Dividend." In Carlo Carraro, Yiannis Katsoulacos, and Anastasios Xepapadeas, eds., *Environmental Policy and Market Structure*. Dordrecht: Kluwer Academic Publishers.
- Bovenberg, A. Lans, and Ruud A. de Mooij, 1994a. "Environmental Levies and Distortionary Taxation." *American Economic Review* 84(4):1085-9.
- Bovenberg, A. Lans, and Ruud A. de Mooij, 1994b. "Environmental Taxation and Labor Market Distortions." *European Journal of Political Economy* 10(4):655-83.
- Bovenberg, A. Lans, and Lawrence H. Goulder, 1996. "Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses." *American Economic Review*, September.
- Bovenberg, A. Lans, and Lawrence H. Goulder, 1997. "Costs of Environmentally Motivated Taxes in the Presence of Other Taxes: General Equilibrium Analyses." *National Tax Journal*, forthcoming March 1997.

³⁹ Similarly, Browning (1997) finds that monopoly pricing exacerbates pre-existing distortions in factor markets. Hence the efficiency costs of monopoly pricing increase with the magnitude of pre-existing factor tax rates. Browning estimates that monopoly pricing in the U.S. is ten times more costly than it would be in the absence of prior factor taxes.

- Bovenberg, A. Lans, and Lawrence H. Goulder, 1998. "Environmental Taxation." In A. Auerbach and M. Feldstein, eds., *Handbook of Public Economics*. New York: North Holland, forthcoming.
- Bovenberg, A. Lans, and F. van der Ploeg, 1994. "Environmental Policy, Public Finance, and the Labour Market in a Second-Best World." *Journal of Public Economics* 55:349-70.
- Browning, E. K., 1997. "The Welfare Cost of Monopoly and Other Output Distortions." *Journal of Public Economics*, forthcoming.
- Browning, E. K., 1987. "On the Marginal Welfare Cost of Taxation." *American Economic Review* 77:11-23.
- Burtraw, Dallas, 1996. "The SO₂ Emissions Trading Program: Cost Savings Without Allowance Trades," *Contemporary Economic Policy*, vol. XIV, no. 2 (April), 79-94.
- Ellerman, A. Denny, and Juan Pablo Montero, 1996. "Why Are Allowance Prices So Low? An Analysis of the SO₂ Emissions Trading Program," CEEPR 96-001, Massachusetts Institute of Technology (February).
- Fankhauser, Samuel, 1994. "The Social Costs of Greenhouse Gas Emissions: An Expected Value Approach." *The Energy Journal* 15:157-84.
- Fullerton, Don, and J. Mackie, 1987. "Investment Allocation and Growth under the Tax Reform Act of 1986." In *Compendium of Tax Research 1987*, Office of Tax Analysis of the U.S. Department of the Treasury, Washington, D.C., pp. 131-171.
- Fullerton, Don and Gilbert Metcalf, 1997. "Environmental Controls, Scarcity Rents, and Pre-Existing Distortions." NBER Working paper 6091, July.
- Goulder, Lawrence H., 1995a. "Environmental Taxation and the 'Double Dividend': A Reader's Guide." *International Tax and Public Finance* 2(2):157-183.
- Goulder, Lawrence H., 1995b. "Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis," *Journal of Environmental Economics and Management*, October.
- Goulder, Lawrence H., Ian W. H. Parry, and Dallas Burtraw, 1997. "Revenue-

- Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions.” *RAND Journal of Economics*, Winter.
- Goulder, Lawrence H., Ian W. H. Parry, Roberton C. Williams III, and Dallas Burtraw, 1998. “The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-best Setting.” *Journal of Public Economics*, forthcoming.
- Goulder, Lawrence H., and Philippe Thalmann, 1993. “Approaches to Efficient Capital Taxation: Leveling the Playing Field vs. Living by the Golden Rule.” *Journal of Public Economics* 50:169-96.
- Hall, Robert, 1988. “Intertemporal Substitution in Consumption,” *Journal of Political Economy* 96(2):339-57.
- Jorgenson, Dale W. and Peter J. Wilcoxon, 1990. “Environmental Regulation and U.S. Economic Growth,” *RAND Journal of Economics* 21(2), 314-340.
- Jorgenson, Dale W. and Peter J. Wilcoxon, 1996. “Reducing U.S. Carbon Emissions: An Econometric General Equilibrium Assessment.” In Darius Gaskins and John Weyant, eds., *Reducing Global Carbon Dioxide Emissions: Costs and Policy Options*. Energy Modeling Forum, Stanford University, Stanford, Calif.
- Jorgenson, Dale, and Kun-Young Yun, 1990. “Tax Policy and the Cost of Capital.” Oxford: Oxford University Press.
- Lawrance, Emily, 1991. “Poverty and the Rate of Time Preference: Evidence from Panel Data,” *Journal of Political Economy* 99(1):54-77.
- Lucas, Robert E., 1990. “Supply-Side Economics: An Analytical Review.” *Oxford Economic Papers* 42:293-316.
- Lee, Dwight R., and Walter S. Misiolek, 1986. “Substituting Pollution Taxation for General Taxation: Some Implications for Efficiency in Pollution Taxation.” *Journal of Environmental Economics and Management* 13:338-347.
- Ng, Y. K., 1980. “Optimal Corrective Taxes or Subsidies when

- Revenue-Raising Imposes an Excess Burden." *American Economic Review* 70:744-51.
- Nordhaus, William D., 1991. "To Slow or Not to Slow: The Economics of the Greenhouse Effect." *The Economic Journal* 101:920-37.
- Oates, Wallace E., 1993. "Pollution Charges as a Source of Public Revenues." In Herbert Giersch, ed., *Economic Progress and Environmental Concerns*. Berlin: Springer-Verlag, pp. 135-52.
- Oates, Wallace E., 1995. "Green Taxes: Can We Protect the Environment and Improve the Tax System at the Same Time?" *Southern Economic Journal* 61(4):914-922.
- Oates, Wallace E., and Robert M. Schwab, 1988. "Economic Competition among Jurisdictions: Efficiency Enhancing or Distortion Inducing?" *Journal of Public Economics* 35:333-354, April.
- Oates, Wallace E., and Diana L. Strassmann, 1984. "Effluent Fees and Market Structure." *Journal of Public Economics* 24:29-46.
- Parry, Ian W. H., 1995. "Pollution Taxes and Revenue Recycling." *Journal of Environmental Economics and Management* 29:S64-S77.
- Parry, Ian W. H., 1997. "Environmental Taxes and Quotas in the Presence of Distorting Taxes in Factor Markets." *Resource and Energy Economics* 19:203-220.
- Parry, Ian W. H., Robertson Williams, and Lawrence H. Goulder, 1998. "When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets." *Journal of Environmental Economics and Management*, forthcoming.
- Parry, Ian W.H., Robertson Williams III, Lawrence H. Goulder, and Dallas R. Burtraw, 1997. "The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting." Working paper, Resources for the Future and Stanford University, August.
- Peck, Stephen C. and Thomas J. Teisberg, 1993. "Global Warming Uncertainties and the Value of Information: An Analysis Using CETA." *Resource and Energy Economics* 15:71-98.

- Pigou, A. C., 1938. *The Economics of Welfare* (4th Edition). London: Weidenfeld and Nicolson.
- Proost, S., and D. van Regemorter, 1995. "The Double Dividend and the Role of Inequality Aversion and Macroeconomic Regimes." *International Tax and Public Finance* 2(2), August.
- Repetto, Robert, Roger C. Dower, Robin Jenkins, and Jacqueline Geoghegan, 1992. *Green Fees: How a Tax Shift Can Work for the Environment and the Economy*. World Resources Institute, November.
- Sandmo, Agnar, 1975. "Optimal Taxation in the Presence of Externalities." *Swedish Journal of Economics* 77.
- Shackleton, Robert, Michael Shelby, Alex Cristofaro, Roger Brinner, Joyce Yanchar, Lawrence Goulder, Dale Jorgenson, Peter Wilcoxon, and Peter Pauly, 1996. "The Efficiency Value of Carbon Tax Revenues." In Darius Gaskins and John Weyant, eds., *Reducing Global Carbon Dioxide Emissions: Costs and Policy Options*. Stanford, Calif.: Energy Modeling Forum.
- Shah, Anwar, and Bjorn Larsen, 1992. "Carbon Taxes, the Greenhouse Effect and Developing Countries," World Bank Policy Research Working Paper Series No. 957. The World Bank, Washington, D.C.
- Terkla, David, 1984. "The Efficiency Value of Effluent Tax Revenues." *Journal of Environmental Economics and Management* 11:107-23.
- Tietenberg, T. H. 1985. *Emissions Trading: An Exercise In Reforming Pollution Policy*. Washington D.C.: Resources for the Future.
- Williams, Roberton C. III, 1998. "Revisiting the Cost of Protectionism: The Role of Tax Distortions in the Labor Market." *Journal of International Economics*, forthcoming.