Tax Deductible Spending, Environmental Policy, and the "Double Dividend" Hypothesis

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Abstract

A number of recent studies have shown that the general equilibrium welfare effects of externality-correcting policies depend importantly on pre-existing taxes in the economy, particularly those that distort the labor market. This paper extends the prior literature by allowing for consumption goods that are deductible from labor taxes. These "goods" represent medical insurance, other less tangible fringe benefits, mortgage interest, and so on. The initial tax system effectively subsidizes tax-favored consumption relative to other consumption, in addition to distorting the labor market.

We find that incorporating tax-favored consumption may overturn key results from earlier studies. In particular, a revenue-neutral pollution tax (or auctioned pollution permits) can produce a substantial "double dividend" by reducing both pollution and the costs of the tax system. The second dividend arises because the welfare gain from using environmental tax revenues to cut labor taxes is much larger when labor taxes also distort the choice among consumption goods. Indeed (ignoring environmental benefits) the overall costs of a revenue-neutral pollution tax are negative in our benchmark simulations, at least for pollution reductions up to 17 percent, and possibly up to 42 percent. In addition, we show that the presence of tax-favored consumption may dramatically increase the efficiency gain from using (revenue-neutral) emissions taxes (or auctioned emissions permits) over grandfathered emissions permits.

Key Words: environmental policies, distortionary taxes, tax deductions, welfare effects

JEL Classification Numbers: H23, Q28, L51

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TAX DEDUCTIBLE SPENDING, ENVIRONMENTAL POLICY, AND THE "DOUBLE DIVIDEND" HYPOTHESIS

Ian W. H. Parry and Antonio Miguel Bento*

1. INTRODUCTION

In recent years there has been a good deal of debate among academics and policy makers about the interactions between environmental policies and the tax system. These debates arose in response to the so-called "double dividend" hypothesis, that is the claim that environmental taxes could simultaneously improve the environment and reduce the economic costs of the tax system. The latter effect seemed plausible, if the revenues from taxes on carbon emissions, gasoline, traffic congestion, household garbage, fish catches, chemical fertilizers, and so on, were used to reduce the rates of pre-existing taxes that distort labor and capital markets. Indeed it was suggested that the overall costs of revenue-neutral environmental taxes might be negative. If so, it would not be necessary to know the benefits from environmental improvement--which are often highly uncertain--in order to justify an environmental tax on cost/benefit criterion.

However, a number of recent analytical and numerical analyses have cast doubt on the validity of the double dividend hypothesis.[1] The basic point is that the hypothesis ignores an important source of interaction between environmental taxes and pre-existing taxes. Since environmental taxes raise the costs of producing output they tend to discourage (slightly) labor supply and investment, and thereby exacerbate the efficiency costs associated with tax distortions in labor and capital markets. In fact, aside from certain special cases, these studies find that the costs from this interaction effect dominate any efficiency benefits from recycling environmental tax revenues in other tax reductions. That is, the presence of pre-existing tax distortions raise the costs of environmental taxes.

The models in the recent literature typically assume a uniform tax on labor (and possibly capital) income with no tax deductions. Thus, in these models the only the only

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[1] We do not go into the details of individual studies here since the rise and fall of the double dividend hypothesis has been discussed at length in other places. For recent surveys of the literature see Bovenberg and Goulder (1998), Parry and Oates (1998), Goulder (1995a) and Oates (1995). Our discussion is concerned with models that assume a competitive labor market, which is probably a reasonable approximation at least for the U.S. economy. The general equilibrium welfare effects of environmental policies are more complex when the labor market contains significant institutional distortions which make the real wage "sticky" (see e.g. Bovenberg and van der Ploeg, 1998).

source of price distortion created by the tax system is in factor markets. However, certain types of spending are (at least partially) deductible from labor taxes. This includes, among other things, spending on mortgage interest, employer-provided medical insurance, and other less tangible fringe benefits.[2] In practice, therefore, the tax system creates an additional source of price distortion: it effectively subsidizes tax-favored spending relative to all other, non-tax-favored spending.

Indeed some recent evidence points to the empirical significance of this second source of economic distortion. Traditionally, estimates of the welfare cost from raising labor taxes to finance government transfers are in the order of 30 cents per dollar of revenue raised--although there is a fair amount of uncertainty concerning these estimates (see e.g., Browning, 1987; Snow and Warren, 1996). These studies focus on the welfare impacts in the labor market alone. However, some very recent work suggests that these welfare costs may be substantially higher--possibly two or three times as high--when the substitution between tax-favored consumption and ordinary (non-tax-favored) consumption is taken into account (Feldstein, 1995a).

This paper extends previous literature by exploring the implications of tax-favored consumption for the general equilibrium costs, and overall welfare effects (benefits less costs) of environmental policies. We model a static economy where households allocate their time between leisure and labor supply. Labor, along with a clean input and a polluting input (e.g., energy or fossil fuels), is used to produce two consumption goods. Expenditure on one of the consumer goods is (partially) deductible from labor taxation. U.S. data on labor market parameters is used to calibrate the model.

At first glance, one might think that if the distortionary costs of pre-existing taxes are greater than assumed in earlier studies, then the general equilibrium costs of new environmental policies would also be greater. However we find the opposite result is typical for environmental taxes with revenues used to cut personal income taxes. That is, the presence of tax-favored consumption can substantially reduce the costs of environmental taxes (relative to their costs in the absence of tax deductions). In fact, results on the double dividend hypothesis established in the earlier literature can easily be overturned, even under very conservative estimates for the costs of pre-existing taxes. In our benchmark simulations, ignoring any environmental benefits, the net impact of an environmental tax swap is to reduce the overall economic costs of the tax system for pollution reductions up to at least 60 percent. In other words the general equilibrium costs of the policy are less than the partial equilibrium costs, and by a potentially substantial amount. Indeed the overall costs of pollution reduction are negative for taxes that reduce pollution by 17 percent, and possibly up to 42 percent. A related point is that, in contrast to typical results from earlier studies (e.g., Bovenberg and

[2] There are a variety of other major deductions from federal income taxes, such as those for pension and charitable contributions, local income taxes, accelerated depreciation, and so on. However, for reasons discussed below we do not consider these other deductions to be relevant for our particular analysis.

Goulder, 1996; Parry, 1995) we find the optimal environmental tax may easily exceed the Pigouvian tax.

These results arise because the welfare gain from using environmental tax revenues to reduce labor taxes is higher, and perhaps substantially so, when labor taxes distort the relative prices among consumption goods in addition to the price of labor. In contrast, (roughly speaking) the interaction effect mentioned above does not change because environmental taxes have approximately the same impact on raising the price of consumption goods relative to leisure. Also, at least in the case when the pollution intensity is the same in both the tax-favored and the non-tax-favored consumption sectors, the environmental tax does not alter the relative price of the two consumption goods, and hence does not exacerbate the costs of the subsidy to tax-favored consumption. Since the gains from recycling environmental tax revenues are larger, while the cost of the interaction effect is not, the welfare costs of the environmental tax are lower--and quite possibly of opposite sign--than in earlier models.

We also explore the implications of tax-favored consumption for the costs of other policy instruments. We find that the costs of non-auctioned pollution emissions permits, or pollution taxes whose revenues are returned lump-sum (rather than used to reduce distortionary taxes), could be significantly greater or significantly less than found in previous studies, depending on the relative pollution intensity of the tax-favored consumption sector. In addition, regardless of the relative pollution intensity, the welfare gain from using revenue-neutral emissions taxes (or auctioned emissions permits) instead of non-auctioned permits can be dramatically higher than suggested by earlier studies. This is due to the larger efficiency gain from using revenues from environmental policies to reduce labor taxes in the presence of tax-favored consumption. In many of our simulations there is much more at stake in whether environmental policies raise revenues, and how these revenues are recycled, than the (partial equilibrium) welfare gain from correcting the environmental externality.

There are a number of important caveats to our analysis (these are discussed in more detail below). First the absolute--though not the relative--costs of emissions taxes and emissions permits are sensitive to the relative pollution intensity of the tax-favored sector. However, even when the polluting input is used significantly less intensively in the tax-favored sector there is still the prospect for a substantial double dividend, at least for modest levels of pollution reduction. Second, in practice the distortion between marginal social benefit and marginal social cost in the market for tax-favored consumption is a good deal more complicated than assumed in our analysis. There are a number of possible eternal benefits, external costs, other regulations, and subsidies that affect the overall size of this distortion. However the empirical importance of these factors, and whether their net impact is to increase or decrease the size of the distortion, is unclear. Third, there is also uncertainty about two other important parameters in our model, namely the elasticity of demand for tax-favored consumption and the labor supply elasticity.

Given these uncertainties, we illustrate the welfare effects of environmental policies over a wide range of scenarios for parameter values, rather than emphasizing specific point estimates. These simulation exercises clearly illustrate the seemingly crucial importance of accounting for tax-favored spending. They also highlight the usefulness of future empirical studies that might provide more accurate estimates of certain key parameters.

The rest of the paper is organized as follows. Section 2 discusses the welfare effects of alternative environmental policies in the presence of tax-favored consumption. Section 3 describes our numerical model and Section 4 provides the simulation results. Section 5 offers conclusions.

2. CONCEPTUAL FRAMEWORK

In this section we explain the general equilibrium welfare effects of alternative environmental policies in the presence of (partially deductible) labor taxation, with the aid of diagrams and certain key formulas. This provides a conceptual framework for interpreting the subsequent numerical results. We provide a more rigorous mathematical model, and the derivation of the formulas, in Appendix A and B.[3] At the end of this section we relate our results to those in earlier studies.

A. Assumptions

Consider a static economy where two final goods *X* and *Y* are produced using labor and intermediate goods. *X* denotes "tax-favored" consumption and represents an aggregate of consumption goods that are (at least partially) deductible from labor taxes. These "goods" include (mortgage interest paid on) owner-occupied housing, other debt-financed spending secured by real estate, child care expenditures, and so on. They also include non-wage compensation such as employer-provided medical insurance, life insurance, business lunches, health clubs, and so on.[4] *Y* denotes an aggregate of consumption goods that do not receive preferential tax treatment.

There is a polluting intermediate good *Z* (e.g. coal), and a clean intermediate good *C*, both of which are produced using labor. Household utility is adversely affected by pollution. For simplicity, assume that pollution damages per unit of *Z* are constant ϕ.[5] In addition we

[3] The mathematical derivations of the welfare effects (see Appendix A) are similar to those in a number of recent models of environmental policies in the presence of labor taxes (e.g. Goulder et al., 1997, 1998; Parry et al., 1998). In particular, the analytical model in Parry et al. would be almost equivalent to that in the current paper, following the introduction of a subsidy for one of the two consumption goods in their household and government budget constraints. Thus, we think there is more value added from using a diagrammatic approach in the above section, in which the intuition is more transparent, and we relegate the (partially repetitive) mathematical proofs to the Appendix.

[4] At first glance it might seem that tax-favored consumption should also include black market activities where cash transactions are not reported as taxable income (possible examples include the hiring of nannies and gardeners). However since these activities are not observed they are implicitly counted as leisure activities, and hence are captured in studies that estimate how taxes affect the substitution from observed labor supply into leisure.

[5] Some other models (e.g. Goulder et al., 1997) allow for the possibility that pollution per unit of the dirty input can be reduced, through the adoption of end-of-pipe abatement technologies. However, this extension has very little impact on the relative welfare impacts of pollution taxes and permits.

assume that production is competitive and characterized by constant returns to scale, therefore supply curves are perfectly elastic.

We represent the tax system by assuming the government levies two taxes on gross labor earnings: a "comprehensive" labor tax t_C and a "non-comprehensive" tax t_N. Expenditure on X is deductible from the non-comprehensive tax but not expenditure on Y. Neither good is deductible from the comprehensive tax.[6] The government returns all revenues in a lump-sum transfer (G) to the household sector.

The (aggregate) household budget constraint amounts to:

$$(1-t_N)p_X X + p_Y Y = (1-t_N - t_C)L + G \tag{2.1}$$

where p_X and p_Y are the producer prices of X and Y which we normalize to unity in the initial equilibrium. L is labor supply, which is responsive to the (net-of-tax) real wage, since households gain utility from leisure. Note that the tax system effectively taxes labor income and subsidizes the consumption of X.

Figure 1 depicts the equilibrium in each of the three distorted markets in the economy. These are the polluting input market (upper panel), the market for tax-favored consumption (middle panel) and the labor market (bottom panel). Demand and supply curves are denoted by "*D*" and "*S*" and initial quantities by subscript 0. MSC^Z denotes the marginal social cost of the polluting input which equals the supply price plus environmental damages per unit. In the labor market the demand curve is perfectly elastic, while the supply curve is upward sloping, reflecting the increasing marginal social cost of labor time.[7]

B. The Welfare Effects of Environmental Policies

Suppose a tax of $t = f$ is imposed on the polluting input and, for the moment, that the revenue consequences of this policy are neutralized by changing the lump sum transfer. The general equilibrium welfare change from this policy consists of the welfare impacts in each of the three distorted markets (see Appendix A for a proof):

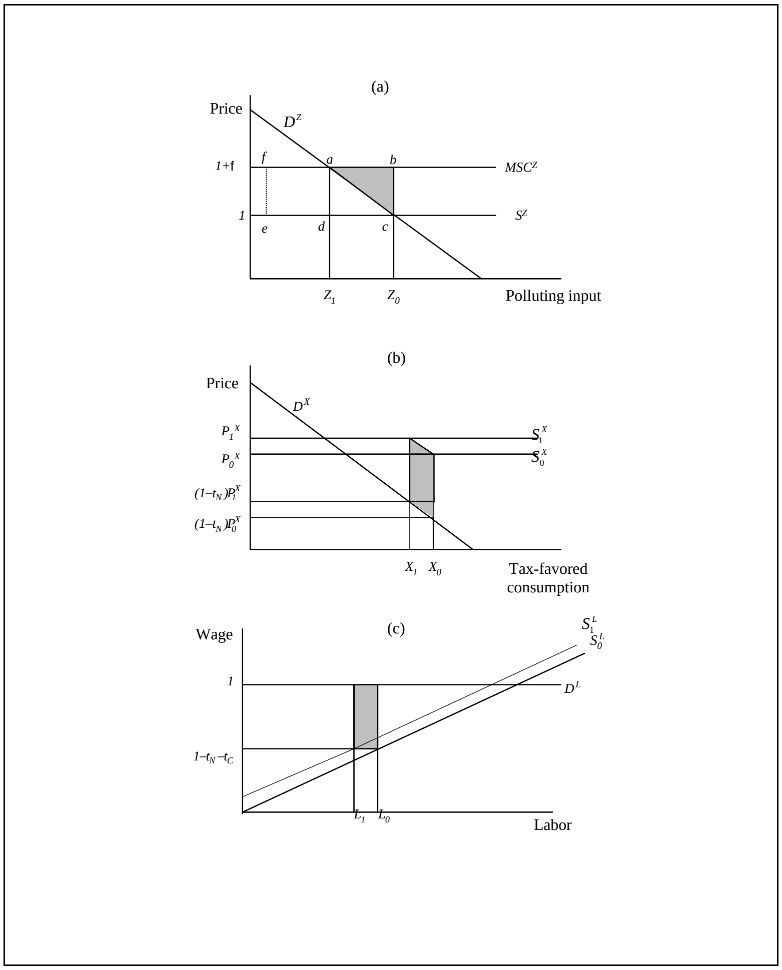
(i) *Pigouvian welfare gain*. Imposing a tax of $t = f$ on the polluting input reduces the quantity to Z_1 in Figure 1(a). This produces environmental benefits equal to rectangle *abcd*, or environmental damages per unit of Z multiplied by the reduction in Z.[8] It also produces economic costs of triangle *acd*, which we call the *primary cost* of the policy. This equals the

[6] In practice some components of X, such as non-wage compensation, are deductible from all labor taxation, that is both personal income and payroll taxes. Other components of X, such as mortgage interest, are deductible from income taxes but not payroll taxes.

[7] Our assumption of constant returns to scale, and that labor is the only primary input, imply a flat labor demand curve. On the supply curve, a worker well to the left of L_0 has a relatively low opportunity cost to being in the labor force and someone well to the right of L_0 would have a relatively high cost to being in the labor force. The latter may represent, for example, the partner of a working spouse who enjoys looking after the house and children.

[8] The change in Z is general equilibrium, that is, after the environmental tax revenues have been returned in extra transfers.

Figure 1


(a)
Price
D^Z
$1+f$
f
a
b
MSC^Z
1
e
d
c
S^Z
Z_1
Z_0
Polluting input
(b)
Price
D^X
P_1^X
P_0^X
S_1^X
S_0^X
$(1-t_N)P_1^X$
$(1-t_N)P_0^X$
X_1 X_0
Tax-favored consumption
(c)
Wage
S_1^L
S_0^L
1
D^L
$1-t_N-t_C$
L_1 L_0
Labor

reduction in consumer surplus (trapezoid acZ_0Z_1), less the reduction in production costs (rectangle dcZ_0Z_1). Environmental benefits less the primary cost leaves the *Pigouvian welfare gain*, equal to the shaded triangle.

(ii) *Subsidy-interaction effect*. In the market for tax-favored consumption there is a wedge of $t_N p^X$ between the supply price (equal to the marginal social cost of *X*) and the demand price (equal to the marginal social benefit). The environmental tax raises the costs of producing *X* and this shifts the supply curve from S_0^X to S_1^X. The demand price increases from $(1-t_N)p_0^X$ to $(1-t_N)p_1^X$ and output falls to X_1. This produces a welfare gain in this market equal to the shaded parallelogram. That is, for each unit reduction in *X* the reduction in social costs exceeds the reduction in consumer benefits by the wedge between the supply and demand price, $t_N p^X$.[9] We refer to this welfare effect as the *subsidy-interaction effect*.

The size of the subsidy-interaction effect relative to the primary cost depends on the size of the parallelogram relative to triangle *acd*. The relative height of these two areas reflects the rate of subsidy relative to the rate of environmental tax. The base of the parallelogram relative to the base of the triangle depends on two important factors. First, the easier it is for firms to substitute other inputs in production (labor and the clean input) for the dirty input *Z*, the smaller will be the change in *X* relative to the change in *Z*. Second, note that *Z* is also an input in the production of *Y* and hence the environmental tax will drive up the price of *Y*. The greater the increase in price of *Y* (relative to the increase in price of *X*) the smaller will be the reduction in *X*. Indeed (as illustrated below) if *Z* is used more intensively in *Y* than in *X* the change in *X* could actually be positive, thereby reversing the sign of the subsidy-interaction effect. Our numerical simulations show that the subsidy-interaction effect is an empirically important determinant of general equilibrium welfare costs when the relative pollution intensity differs markedly across the *X* and *Y* industries.

(iii) *Tax-interaction effect*. The position of the labor supply curve in Figure 1(c) depends on the prices of consumption goods. In particular, the increase in price of *X* and *Y* caused by the environmental tax reduces the amount of consumption that can be purchased from a given nominal (net-of-tax) wage. That is, the environmental tax indirectly reduces the return to work effort relative to leisure and this typically causes the labor supply curve to shift upwards (slightly) to S_1^L. Labor supply falls from L_0 to L_1 and this produces a welfare loss equal to the shaded rectangle. This rectangle equals the wedge between the gross wage (unity)--which equals the value marginal product of labor--and the net of tax wage ($(1-t_N-t_C)$)--which equals the opportunity cost of an incremental reduction in leisure--multiplied by the reduction in labor

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[9] This is a simple application of the familiar formulas for the general equilibrium welfare effect of a new tax in the presence of pre-existing price distortions (see e.g. Harberger, 1974, chapters. 2 and 3, and Appendix A below). Note that a new tax causes a second-order welfare effect (i.e. triangle) in the market where it is imposed (in this case the polluting input market). It causes a first-order welfare effect (a rectangle or parallelogram) in any other market of the economy where quantities change and where there is a pre-existing price distortion (in this case an output market).

supply. This is the *tax-interaction effect*, which is familiar from other studies (e.g. Goulder et al., 1997; Parry, 1995).

For the environmental tax with lump-sum replacement these three components constitute the general equilibrium welfare effect of the policy (Appendix A). Now however, suppose that one of the two labor taxes adjusts to maintain budget balance instead of the lump-sum transfer. In this case an additional welfare effect comes into play.

(iv) *Revenue-recycling effects*. The net revenue received by the government is somewhat less than the revenue raised in the polluting input market, f Z_1 in Figure 1(a), due to the loss of labor tax revenues in Figure 1(c).[10] Suppose net revenues equal rectangle *fade* in Figure 1(a). If this revenue is used to reduce the non-comprehensive tax instead of increasing the lump-sum transfer, this produces two sources of welfare gain. First, this (slightly) raises the net-of-tax wage leading to an increase in labor supply. Second, it also (slightly) reduces the relative subsidy for *X* and therefore induces a substitution out of tax-favored consumption and into non-tax-favored consumption.[11] The combined welfare gain from these two effects, per dollar of revenue recycled, is denoted MEB^N. This is equivalent to the marginal excess burden (MEB) of non-comprehensive labor taxation, that is the welfare cost from spending an extra dollar of lump-sum transfers financed by increasing the non-comprehensive labor tax. The total welfare gain from using the pollution tax revenues to cut the non-comprehensive labor tax is MEB^N times rectangle *fade*. We refer to this as the *revenue-recycling effect*.[12]

Suppose instead that net revenues are used to reduce the comprehensive labor tax. In this case there is a similar welfare gain in the labor market, but no gain from reducing the subsidy wedge in the market for tax-favored consumption. Therefore (for the same amount of revenues raised) the welfare gain from the revenue-recycling effect is smaller, MEB^C times rectangle *fade*, where MEB^C is the MEB for the comprehensive labor tax and $MEB^C < MEB^N$. We say there is a "strong" revenue-recycling effect when the non-comprehensive labor tax is reduced and a "normal" revenue-recycling effect when the comprehensive labor tax is reduced.

Emissions Permits

Now suppose the quantity of the polluting input is reduced to Z_1 in Figure 1(a) by issuing the appropriate quantity of pollution permits. This policy induces the same Pigouvian welfare gain as the environmental tax. It also induces an analogous subsidy-interaction effect

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10 Although this revenue loss is partially offset to the extent that tax-favored consumption falls. The direct revenues from the environmental tax are likely to easily dominate the loss of labor tax revenues, except when environmental taxes approach prohibitive levels (Parry, 1995).

11 The welfare gain in the labor market is (approximately) equal to the increase in labor supply multiplied by the wedge between the gross and net wage. The welfare gain in the *X* market equals (approximately) the reduction in *X* multiplied by the rate of non-comprehensive tax.

12 The revenue-recycling and tax-interaction effects are familiar from earlier studies. For ease of exposition, we use a slightly different definition here. Other studies (e.g. Parry, 1995; Goulder et al., 1997) add on the welfare loss from the reduction in labor tax revenues to the cost of the tax-interaction effect, rather than subtracting it from the revenue-recycling effect, as we have above.

and tax-interaction effect because it raises the price of the polluting input to the same level $(1+\phi)$. The permit policy creates rents of rectangle ϕZ_1. If the permits were auctioned the rents would accrue to the government and the general equilibrium welfare effect of the policy would be identical to that of the environmental tax in our model.

Instead, in keeping with practice so far in U.S. pollution control programs, we assume the permits are given out for free to existing firms. In this case the rents accrue to the private sector. The government does (indirectly) receive a fraction of these rents because rents are reflected in firm profits (which are subject to corporate income tax) and ultimately non-labor household income (which is subject to personal income tax). However, this revenue gain is (slightly) more than offset by the reduction in labor tax revenues in our simulation results.

C. Relation to Previous Studies

In previous studies (e.g. Goulder et al., 1997; Bovenberg and de Mooij, 1994; Parry, 1995) there is no allowance for tax-favored spending and hence no distortion in the *X* market in Figure 1(b).[13] The general equilibrium cost of a revenue-neutral pollution tax in these models therefore consists of the primary costs, the tax-interaction effect, and the normal revenue-recycling effect. These studies typically find that the cost from the tax-interaction effect dominates the benefit from the normal revenue-recycling effect. Therefore, the net impact of environmental tax swaps is to reduce labor supply and increase the costs of pre-existing taxes.[14] These studies therefore cast doubt on the "double dividend" hypothesis, that is the claim that environmental taxes could both improve the environment and reduce the costs of the tax system at the same time.[15]

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[13] Lawrence Goulder has used a sophisticated dynamic numerical model of the US economy to conduct a number of exercises that examine the effects of environmental taxes (see e.g. Goulder, 1995b). Although it allows for a detailed treatment of the tax system, this model does not incorporate tax deductions for medical insurance and mortgage interest.

[14] These results are consistent with earlier results from the public finance literature (see e.g. Sandmo, 1976). The environmental tax swap effectively substitutes revenues from a tax with a relatively narrow base (for example fossil fuels or energy output) for revenues from a tax with a very broad base (economy-wide labor income). Narrow based taxes typically involve higher costs because the substitution possibilities for avoiding the tax are much greater than when the tax has a broad base.

[15] This hypothesis stems from analyses that essentially "tack on" the revenue-recycling effect to a partial equilibrium analysis of environmental taxes. Since they are not general equilibrium, these analyses fail to capture the crucial tax-interaction effect. A double dividend could however arise in some special cases. For example, if output from the polluting sector is a relatively weak substitute (or complement) for leisure compared with other market outputs then the revenue-recycling effect can dominate the tax-interaction effect (this may apply, for example, in the case of cigarette taxation or taxes on polluting inputs in agriculture). Also, to some extent incorporating capital can either strengthen or weaken the results from static, one-factor models. This depends on the extent to which the MEB of labor and capital taxes differ and the extent to which the environmental tax swap may shift the overall burden of taxation from one factor to another. Finally, changes in environmental quality may have feedback effects that affect the labor/leisure decision. These feedback effects are not captured in the empirical models because they are difficult to quantify. We abstract from all these complications below since they have been discussed at length in the literature (see e.g. the survey in Bovenberg and Goulder, 1998).

Our numerical results below differ from those in these earlier studies because of the subsidy-interaction effect, and more importantly to the extent that the strong and normal revenue-recycling effects differ. The ratio of the strong to the normal revenue-recycling effect equals MEB^N/MEB^C. In Appendix B we derive the following formula for MEB^N (when $\tau = 0$ and we ignore feedback effects on the environment):

$$MEB^N = \frac{\frac{t}{1-t}\varepsilon_L^H + \frac{t_N}{1-t_N} s_X \eta_X^H}{1 - \frac{t}{1-t}\varepsilon_L^M - s_X\left\{1 + \frac{t_N}{1-t_N}\eta_X^M\right\}} \tag{2.2}$$

where ε_L^M and ε_L^H are the uncompensated (Marshallian) and compensated (Hicksian) labor supply elasticities, η_X^M and η_X^H are the uncompensated and compensated own price elasticity of demand for tax-favored consumption (expressed as positive numbers), s_X is the share of tax-favored consumption in total consumption and $t = t_C + t_N$ is the total labor tax wedge. Setting $t_N=0$ gives:

$$MEB^C \cong \frac{\frac{t}{1-t}\varepsilon_L^H}{1 - \frac{t}{1-t}\varepsilon_L^M} \tag{2.3}$$

The formula in (2.3) has been discussed at length in other studies (see e.g. Browning, 1987, and Snow and Warren, 1996) and we do not go into details here.[16] For our purposes the key point here is that the increase in the MEB because of tax-favored consumption depends on three key parameters (which we discuss below): the relative size of the tax-favored consumption sector, the (compensated and uncompensated) demand elasticity for tax-favored consumption, and the subsidy wedge.

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[16] These formulas are for an increase in labor taxation to finance an extra dollar of the lump-sum transfer. If the extra revenue were not returned to households (for example it went out of the economy in foreign aid) all the elasticities would be uncompensated, while if the extra public spending was sufficient to keep household utility constant all the elasticities would be compensated. In our case the formulas depend on both uncompensated and compensated elasticities because the extra revenue to be recycled from an incremental increase in t ($L+tdL/dt$ in the case of (2.3)) does not fully compensate households for the loss in surplus from the tax increase (L). The formula in (2.3) is exact when $t_N=0$, as in previous studies. The MEB for the comprehensive tax in our model is a little more complicated due to a cross-price effect in the X market, however in quantitative terms the difference is very small.

3. NUMERICALLY-SOLVED MODEL

We now perform numerical simulations to compare, empirically, the welfare impacts of alternative environmental policies. Subsections A and B describe the assumed functional forms and model calibration underlying the simulations. Due to uncertainty over the values of key parameters, we consider "low", "medium" and "high" scenarios for the distortionary costs of the tax system.

A. Functional Forms

The household has the following constant elasticity of substitution (CES) form for utility:

$$U = \left\{ \alpha_U C^{\frac{\sigma_U - 1}{\sigma_U}} + (1-\alpha_U)(\bar{L} - L)^{\frac{\sigma_U - 1}{\sigma_U}} \right\}^{\frac{\sigma_U}{\sigma_U - 1}} - \phi(Z) \qquad (3.1)$$

$$C = \left\{ \alpha_C X^{\frac{\sigma_C - 1}{\sigma_C}} + (1-\alpha_C) Y^{\frac{\sigma_C - 1}{\sigma_C}} \right\}^{\frac{\sigma_C}{\sigma_C - 1}} \qquad (3.2)$$

where C denotes composite consumption or sub-utility from the consumption of goods and the σ's and α's are parameters. σ_U and σ_C denote the elasticities of substitution between composite consumption and leisure, and between individual consumption goods, respectively. The α's are share parameters. $\phi(.)$ is disutility from the pollution caused by the dirty input Z, where $\phi'>0$, $\phi''\geq 0$.

There are two notable restrictions embedded in this utility function. First, the separability assumption in (3.1) simplifies our analysis by ruling out possible feedback effects of changes in environmental quality on the labor/leisure decision and the choice among consumption goods.[17] Second, the weak separability between leisure and consumption goods, and the homothetic property of (3.2) together imply that X and Y are equal substitutes for leisure.[18] This seems a reasonable benchmark assumption, given that we know of no evidence to suggest that the degree of substitution between tax-deductible consumption and leisure is significantly stronger or weaker than the degree of substitution between other consumption goods and leisure.

X and Y are produced using the polluting intermediate good (Z), a clean intermediate good (H), and labor using the following CES production functions:

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[17] One possible feedback effect might occur in the case of traffic congestion. Under certain conditions, a congestion tax on work-related traffic can increase the household wage net of commuting costs, and hence raise the labor force participation rate at the margin. Another example is the possibility that reduced pollution will raise worker productivity by improving human health (see e.g. Williams, 1998).

[18] See Deaton (1981) for a proof. For a discussion of how the relative degree of substitution between goods and leisure alters the welfare impact of environmental policies, see e.g. Boveneberg and Goulder (1998) and Parry (1995).

$$X = X\left\{\alpha_D^X Z_X^{\frac{\sigma_X - 1}{\sigma_X}} + \alpha_C^X C_X^{\frac{\sigma_X - 1}{\sigma_X}} + \alpha_L^X L_X^{\frac{\sigma_X - 1}{\sigma_X}}\right\}^{\frac{\sigma_X}{\sigma_X - 1}} \tag{3.3}$$

$$Y = Y\left\{\alpha_D^Y Z_Y^{\frac{\sigma_Y - 1}{\sigma_Y}} + \alpha_C^Y C_Y^{\frac{\sigma_Y - 1}{\sigma_Y}} + \alpha_L^Y L_Y^{\frac{\sigma_Y - 1}{\sigma_Y}}\right\}^{\frac{\sigma_Y}{\sigma_Y - 1}}$$

where σ_X and σ_Y are the elasticity of substitution between inputs in the two industries and the α's are input share parameters, and

$$Z = Z^X + Z^Y; \qquad H = H^X + H^Y \tag{3.4}$$

Labor is the only input used to produce *Z* and *H* and the marginal product of labor in each of these intermediate goods industries is taken to be constant and normalized to unity. Thus:

$$Z = L^Z; \qquad H = L^H \tag{3.5}$$

Labor market equilibrium requires:

$$L^X + L^Y + L^Z + L^H = L \tag{3.6}$$

That is, labor demanded by final and intermediate good industries equals labor supplied by households.

As discussed above, the government provides a lump-sum transfer (*G*), levies a comprehensive tax (t_C) and non-comprehensive tax (t_N) on labor income, and reduces *Z* either by a pollution tax (τ) or pollution permits. We assume the government budget must balance. In the case of the pollution tax this constraint is:

$$G = (t_C + t_N)L - t_N p_X X + \tau Z \tag{3.7}$$

That is, government spending equals labor tax revenues less deductions plus pollution tax revenue.

Households choose *X*, *Y* and *L* to maximize utility subject to the budget constraint given by (2.1). This generates the demand functions for goods and the labor supply function. Firms choose inputs to minimize production costs and this determines costs per unit of output, or producer prices. In equilibrium demand and supply are equated in the final goods, inter-mediate goods, and labor markets, and the household and government budget constraints are satisfied.[19]

B. Model Calibration

The consumption/leisure substitution elasticity (σ_U) is calibrated to be consistent with estimates of labor supply elasticities. The econometric evidence on labor supply elasticities has been reviewed many times and we do not go into the details here (see e.g. Killingsworth,

[19] We used GAMS with MPSGE to solve the model.

1983). For our purposes there are several important points. First, for our highly aggregated model the labor supply response to changes in net wages represents the impact on average hours worked per employee and the impact on the participation rate, averaged across all members (male and female) of the labor force. Second, despite numerous studies, there is still a fair amount of uncertainty over the economy-wide labor supply elasticity, and therefore it prudent to consider a range of values. Third, our model should be consistent with estimates for both the compensated and uncompensated labor supply elasticity. In our medium scenario for the MEB of pre-existing taxes, we choose the consumption/leisure elasticity and the initial ratio of labor supply to the time endowment to imply an uncompensated and a compensated labor supply elasticity of 0.15 and 0.4 respectively. These are typical values used in previous studies of environmental policies (e.g. Goulder et al., 1997). In our low and high MEB scenarios we use values of 0.1 and 0.3, and 0.25 and 0.5 respectively.[20] Following other studies (Lucas, 1990; Goulder et al., 1997), we assume a marginal tax wedge in the labor market of 40 percent, which reflects the combined effects of personal, payroll and sales taxes.

The two largest components of tax-favored spending are employer provided medical insurance and homeowner mortgage interest. These items amounted to about 5 percent and 4 percent respectively, of total consumption expenditures in 1995.[21] There are a variety of other quantifiable items that add about another 4 percent.[22] In addition, there are other categories that are difficult to measure, such as business lunches and trips, employer-provided health clubs, debt-financed spending secured by real estate, and so on.[23] In short, it is tricky to pin down really accurately the relative size of the tax-favored consumption sector. We assume s_X = 0.1, 0.15 and 0.2 in our low, medium, and high MEB scenarios, respectively.

If all tax-favored consumption were fully deductible from labor taxes, the subsidy wedge in the market for tax-favored consumption would be 40 percent in our model. This is not quite

[20] These values are roughly consistent with a recent survey of opinion among labor economists by Fuchs et al. (1998), assuming a weight of 0.6 and 0.4 for the male and female elasticities reported in their Table 2.

[21] Direct estimates of these items overstate tax-favored spending, for example mortgage payments include repayment of principal, which is not tax-deductible. To obtain the above values we used estimates of losses in personal income tax revenues from these deductions from Table 523 in the *Statistical Abstract of the United States* (1995), divided by the marginal rate of personal income tax (assumed to be 0.25 percent for the average taxpayer).

[22] In this list of categories in Table 523 we include employee parking, life insurance, child care, medical claims (rather than premiums), workman's compensation benefits and deductions for taxes paid on home sales.

[23] In fact we include less than 40 percent of deductions from federal income taxes in our definition of X. We exclude pension contributions, since this tax deduction is offset at least to some extent by future taxes on the income from savings. For more discussion of this issue see Feldstein (1995a), pp. 34-37. Although charitable contributions are tax-deductible, they may also confer important external benefits. We exclude charitable contributions to avoid getting into the messy business of estimating externality benefits. There are a variety of other deductions listed in Table 523 of the Statistical Abstract, but which are not really relevant for our analysis. For example deductions for capital expenditures and savings are not relevant because our analysis is static and does not capture pre-existing taxes on capital. In addition, deductions for local income taxes reduce the overall rate of labor tax but do not distort the allocation of consumption expenditures.

the case however, and we assume a subsidy of 30 percent.[24] As discussed in Section 4, we abstract from a number of other complications that affect the overall size of the subsidy wedge.

It is difficult to assess the overall demand elasticities for tax-favored consumption. These are determined by the elasticity of substitution between tax-deductible consumption and other consumption goods, and s_X, as follows: $\eta_X^M = (1-s_X)\sigma_C + s_X$ and $\eta_X^H = (1-s_X)\sigma_C$. Various studies have estimated demand elasticities for individual components of *X*. For example, Rosen (1979) estimated the (uncompensated) demand elasticity for home mortgages to be unity. A recent estimate of the demand elasticity for health insurance is 1.8 (Gruber and Poterba, 1994).[25] We choose σ_C to imply values of 1, 1.25 and 1.6 for the uncompensated demand elasticity for *X* in our low, medium and high MEB scenarios.

Table 1 summarizes our key parameter values. They imply an MEB from the non-comprehensive tax equal to 0.31, 0.50 and 0.91 in the low, medium and high scenarios. In earlier studies that neglect tax-favored consumption (e.g. Goulder et al., 1997) the MEB is around 0.3, which equals our MEB for the comprehensive tax in the medium scenario. At first glance it may seem surprising that the presence of tax-favored consumption increases the MEB so much, when tax-favored consumption is only around 10-20 percent of the size of the labor market. However, this is roughly offset because tax-favored consumption is much more sensitive to changes in tax rates than labor supply.

Table 1. Alternative Scenarios for Key Parameters

Parameter	Low MEB	Medium MEB	High MEB
s_X	0.10	0.15	0.20
η_X^M	1.00	1.25	1.60
η_X^H	0.85	1.10	1.40
ε_L^M	0.10	0.15	0.25
ε_L^H	0.30	0.40	0.50
MEB^N	0.30	0.50	0.91
MEB^C	0.21	0.30	0.40

Note: See Section 2 for notational definitions.

[24] In particular mortgage interest is only deductible from the personal income tax, and not the payroll tax. It is subsidized at the marginal rate of income tax (averaged across individuals) which is around 25 percent. Our assumptions about tax rates and s_X imply government revenue is 34-37 percent of total spending in our benchmark, which is approximately consistent with the ratio of total tax receipts to net national product. Note that our strong revenue-recycling effect implicitly assumes that environmental tax revenues are used to cut the rate of personal income tax. The revenue-recycling effect would be somewhat smaller if revenues were used to cut the payroll tax, since this tax has less deductions.

[25] Earlier studies typically find significantly lower estimates, however Gruber and Poterba suggest that these studies contain a number of methodological problems.

In fact, our parameter assumptions appear to be conservative in light of a recent study by Feldstein (1995a). He found that the MEB for the personal income tax could easily exceed a dollar, when all substitution possibilities for avoiding the tax increase are taken into account. To obtain this value, Feldstein used estimates from several recent studies of the elasticity of the personal income tax base with respect to changes in tax rates. This elasticity reflects a combination of labor supply effects and substitution into tax-deductible spending. Feldstein's results suggest that--even in our high MEB scenario--we could be significantly understating s_X and the elasticities for tax-favored consumption and labor supply. The relationship between our parameter values and Feldstein's estimates are discussed in more detail in Appendix C.[26]

We take the elasticities of substitution in the X and Y industries (s_X and s_Y) to be unity. This is a standard assumption and our results are not sensitive to other values. In our initial simulations the factor input ratios are initially the same in both consumption goods industries, but this is relaxed later on. Finally, we assume the initial value of output in each intermediate good industry amounts to 10 percent of the value of total final output. The relative costs of environmental policies are not especially sensitive to alternative assumptions about the size of the polluting sector in GDP (this finding is consistent with earlier studies).

4. RESULTS

This section presents our simulation results illustrating how the tax system affects the costs, overall welfare impacts, and optimal levels of environmental policies. We also discuss some important caveats to the results.

A. Marginal Costs

In Figure 2 we compare the marginal cost of reducing pollution under alternative policy instruments up to 50 percent below pre-regulation levels. Marginal costs are expressed as a percent of the initial value product of the polluting input. For this figure we mainly focus on qualitative results, and since these are essentially the same under all three MEB scenarios, we just illustrate the medium MEB case.

MC^{PRIM} indicates marginal costs in a first-best case when we set pre-existing taxes and the subsidy to zero. This curve reflects primary costs only and is the same under both the pollution tax and pollution permits.[27] MC^{PRIM} has a zero intercept, and is upward sloping, reflecting the increasing marginal cost of substituting other inputs for the polluting input in production and the increasing marginal cost of reducing the amount of consumption.

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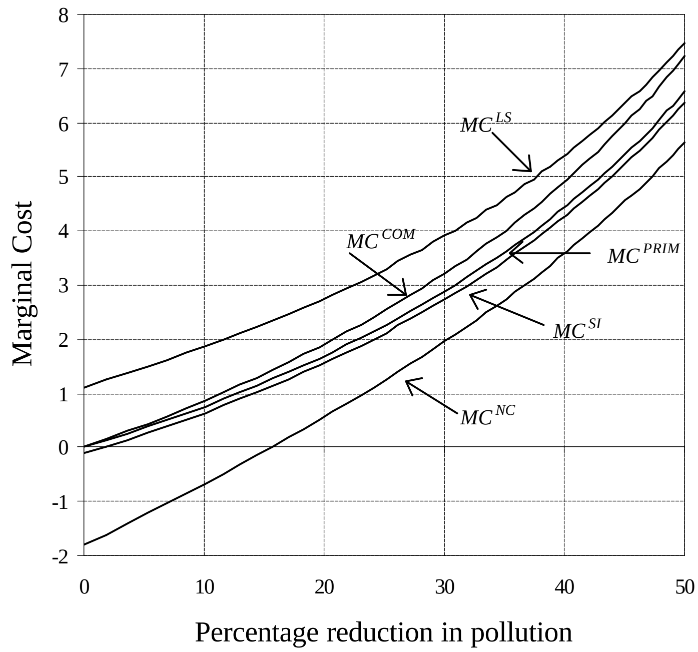
[26] We prefer not to commit ourselves to "best guesses" for these parameters until more evidence becomes available. Instead we illustrate a range of outcomes under plausible values. The labels low, medium, and high MEB scenarios are used for convenience--they do not reflect any views about "most likely" parameter values.

[27] To calculate the primary costs we re-calibrate the distribution parameters such that the initial quantity of goods and leisure are the same as in the model with non-zero taxes. However the substitution elasticity parameters, which crucially determine the relative costs of policies, are the same across the models with and without the labor taxes.

Figure 2. Marginal Costs



MC^{SI} shows marginal costs when we allow for the 30 percent subsidy for *X*, but still set labor taxes at zero.[28] The difference between this curve and MC^{PRIM} reflects the (marginal) subsidy-interaction effect. This effect is a welfare gain (the parallelogram in Figure 1(b)) because the pollution tax reduces the output of *X*, thus offsetting to some extent the distortionary effect of the subsidy. However, the subsidy-interaction effect is not very large. This is because the price of *X* and *Y* increase in the same proportion, and hence the reduction in *X* reflects substitution into leisure only and not into other consumption. Subsequent simulations show, however, that the subsidy-interaction effect can be important when the relative pollution intensity differs significantly between the tax-favored and non-tax-favored production sectors.

MC^{LS} indicates marginal cost under the pollution tax with both labor taxes but with no revenue-recycling effect; that is, environmental tax revenues are neutralized by adjusting the lump-sum transfer. The difference between this curve and MC^{SI} reflects the (marginal) tax-interaction effect. Thus the tax-interaction effect causes a substantial upward shift of the marginal cost curve (see Goulder *et al*. (1997) for more discussion).

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28 For this case the subsidy is financed by a (negative) lump-sum transfer, and the lump-sum transfer is adjusted to neutralize the revenue effects of environmental policies.

MC^{COM} shows marginal costs under the pollution tax with revenues used to reduce the comprehensive tax (holding government transfers constant in real terms). It equals MC^{LS} less the (marginal) benefit from the normal revenue-recycling effect. Comparing MC^{COM} with MC^{SI} we can infer that the tax-interaction effect dominates the normal revenue-recycling effect at the margin (except at zero pollution reduction). Again, this result is familiar from other studies (e.g. Goulder et al., 1997). The gap between MC^{LS} and MC^{COM} decreases with the amount of pollution reduction, since the erosion of the pollution tax base reduces the marginal revenue-recycling effect. Indeed the marginal revenue-recycling effect eventually becomes negative if pollution is reduced by more than a certain amount. Beyond this point the pollution tax Laffer curve is downward sloping and MC^{COM} rises above MC^{LS}.

Finally, MC^{NC} is the marginal cost curve for the pollution tax with revenues used to reduce the non-comprehensive labor tax.[29] This curve equals MC^{LS} less the (marginal) benefit from the strong revenue-recycling effect. It has a negative intercept and marginal costs are negative up to a pollution reduction of 15 percent in our medium cost scenario. Thus, even if there were no environmental benefits it would still be optimal to reduce pollution by 15 percent in this case. Up to a point therefore, the environmental tax swap reduces the overall costs of the tax system, not counting environmental benefits. It makes the tax system more efficient by effectively reducing the net subsidy for tax-favored consumption.[30] On the other hand, the environmental tax is more distortionary than the labor tax in the sense that it excludes non-polluting inputs from the tax base. At least for more modest levels of pollution tax, the advantage from the former effect outweighs the disadvantage from the latter effect.

B. Total Costs

Figure 3 shows the total (as opposed to marginal) costs of reducing pollution under various policies, expressed relative to the total primary costs. When a cost curve lies above (below) unity, the net impact of the tax system is to raise (lower) the overall cost of a policy above (below) its primary costs.

The most novel feature of Figure 3 is the total cost curves for the pollution tax with revenues used to reduce the non-comprehensive labor tax, denoted TC^{NC}, which are shown for the low, medium and high MEB scenarios. These curves lie below the horizontal axis for pollution reductions up to between 17 and 42 percent. When total costs are negative the welfare gain from reducing the costs of the tax system more than offset the primary cost of the policy. Goulder (1995a) refers to this as a "strong" double dividend from environmental taxes. When total costs are positive but less than unity, there is still a net welfare gain from interactions with the tax system. This is referred to as an "intermediate" form of the double

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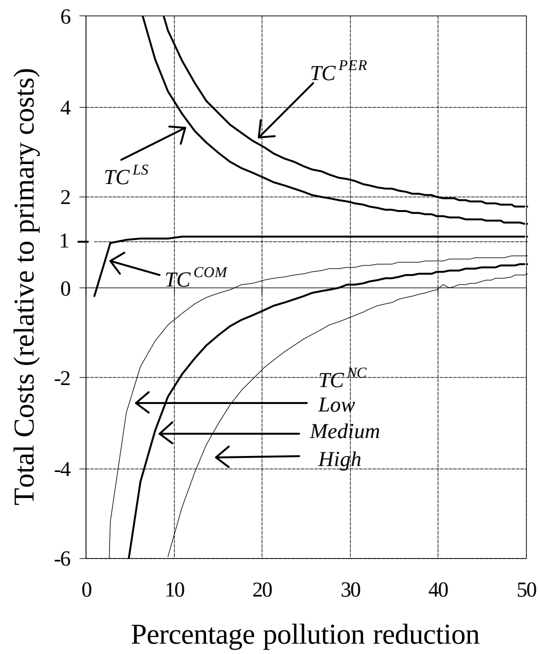
29 To avoid cluttering Figure 2, we omit marginal costs for emissions permits in the presence of pre-existing taxes. The effects of this policy are explained below.

30 If the were no tax deductions in our model (and no environmental effects), the labor tax would always be more efficient than the pollution tax for raising revenues.

dividend in Goulder (1995a). For example in the medium MEB scenario, if the reduction in pollution is below 50 percent, interactions with the tax system reduce the overall costs of the pollution tax by over 50 percent.[31]

Figure 3. Total Costs



In contrast, if revenues are instead used to reduce the comprehensive labor tax total costs are indicated by TC^{COM} in the medium cost scenario. In this case there is no potential for a double dividend; the general equilibrium costs of this policy exceed the primary costs by around 12 percent.[32] Figure 3 clearly shows that--by neglecting the welfare gain from the

[31] Thus, for more modest levels of pollution taxation there is potential for quite a huge double dividend, but this declines at higher levels of pollution taxation. The reason for this is clear from Figure 1. At modest levels of pollution taxation, the net revenues raised, and hence the (strong) revenue-recycling effect, are large relative to the primary cost triangle *acd*. But at high levels of pollution taxation the base of the tax is much smaller, and this reduces the size of the strong revenue-recycling effect relative to primary costs. At 100 percent pollution reduction there are no revenues raised under any policies, and the total costs of all the policy instruments we consider become equal.

[32] Previous studies (e.g. Goulder et al., 1998) find slightly higher cost ratios for this policy. This is because they use a slightly different definition of the denominator in the cost ratio. The difference between the TC^{NC} and TC^{COM} curves in Figure 3 is a little larger than can be explained by the difference between the strong and normal revenue recycling effects alone. The reason is a little technical. When the recycling of pollution tax revenues reduces the subsidy distortion for tax-favored consumption this raises the relative attractiveness of work effort to

reduced subsidy for tax-favored consumption--previous studies may dramatically overstate not only the magnitude of costs from environmental tax swaps, but also the sign of the welfare change. For example, for a pollution reduction of 20 percent in the medium MEB scenario, previous studies would estimate costs equal to 112 percent of primary costs; in contrast our analysis predicts a welfare *gain* equal to 50 percent of primary costs.

When the revenue effects of environmental taxes are neutralized by lump-sum transfers, total costs are given by TC^{LS} in the medium MEB case. The overall costs of this policy are infinitely larger than the primary costs for an incremental amount of pollution reduction. This reflects the positive intercept of the marginal cost curve for this policy in Figure 2. As the extent of pollution reduction increases, total costs fall relative to the primary cost. This is because the primary cost triangle *acd* in Figure 1(a) increases relative to the cost of the tax-interaction effect, the shaded rectangle (for more discussion see Goulder et al., 1997). Finally, TC^{PER} is the (general equilibrium) total cost of reducing pollution by emissions permits, relative to the primary cost, when government budget balance is maintained by adjusting the comprehensive labor tax. Although we assume that 40 percent of permit rents accrue to the government in tax revenue, this is not quite enough to compensate for the reduction in labor tax revenues, hence tax rates must be increased slightly to maintain government budget balance and TC^{PER} lies above TC^{LS}.[33]

Previous studies have emphasized the potentially strong efficiency case for using (revenue-neutral) pollution taxes--or equivalently in our analysis, auctioned emissions permits--over non-auctioned emissions permits (see Parry, 1997; Goulder et al., 1997; Parry et al., 1998). This case is based on a comparison of total cost curves that (roughly speaking) correspond to TC^{COM} and TC^{PER} in Figure 3. However, when recycling the revenues from the pollution tax or permit sales produces a welfare gain in the market for tax-favored consumption, in addition to the welfare gain in the labor market, the appropriate comparison is between the TC^{NC} curves and (approximately) TC^{PER} in Figure 3. In this case, the efficiency cost savings from using the pollution tax or auctioned permits over free pollution permits is potentially much more dramatic. For example, if pollution is reduced by 20 percent, the cost of emissions permits is more than 300 percent of primary costs; in contrast the pollution tax or auctioned permits produces an economic gain equal to 50 percent of primary costs in the medium MEB scenario. As consistent with earlier studies, however, the cost saving from using the pollution tax over emissions permits is relatively less dramatic at higher levels of pollution reduction.

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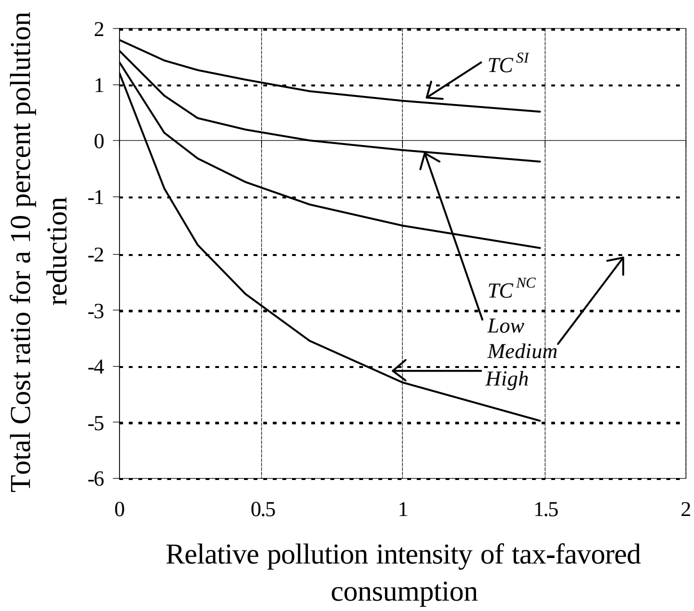
leisure at the margin. As a result the overall reduction in labor supply is slightly smaller when there is a strong rather than a normal revenue-recycling effect (in fact the overall change in labor supply is slightly positive for modest pollution reducitons).

[33] If the non-comprehensive tax is adjusted to maintain budget balance, total costs are slightly higher than indicated by TC^{PER}.

C. Relative Pollution Intensities

We now relax the assumption of equal pollution intensities in the tax-favored and non-tax-favored production sectors. This affects the costs of policies by changing the relative size of the subsidy-interaction effect. Along the horizontal axis in Figure 4 we vary the (initial) ratio of the polluting input to the clean input in the tax-favored sector, relative to the same share in the non-tax-favored sector (keeping the total amount of pollution the same). This ratio is less (greater) than unity when tax-favored consumption is less (more) pollution intensive than non-tax-favored consumption.

Figure 4. Varying the Pollution Intensity of Tax-Favored Consumption



The TC^{SI} curve shows the total costs of reducing pollution by 10 percent in the medium MEB case, expressed relative to the primary costs, when there is a 30 percent subsidy for *X* but labor taxes are zero. The gap between this curve and unity isolates the subsidy-interaction effect. As the relative pollution intensity in the tax-favored sector falls (moving left along the horizontal axis), the welfare gain from the subsidy interaction effect declines, and becomes negative (this occurs when TC^{SI} curve rises above unity and the pollution intensity ratio is less than .57). This is because the pollution tax drives up the price of non-tax-favored consumption by a proportionally greater amount, hence reducing, and eventually reversing the direction of, the change in tax-favored consumption.

The TC^{NC} curves show the total costs of the pollution tax with the strong revenue-recycling effect relative to primary costs, for a 10 percent pollution reduction. As the relative pollution intensity of tax-favored consumption falls, the costs of this policy increase as the subsidy-interaction effect declines and becomes negative. In fact, when the intensity ratio falls below .72, .20, or .10 in the low, medium and high MEB scenarios, total costs are positive, hence the strong double dividend disappears.

Thus our results are sensitive to the relative pollution intensity of the tax-favored sector. Even the intermediate form of the double dividend disappears in the limiting case when polluting inputs are used exclusively in the non-tax-favored sector (e.g. chemical pesticides and fertilizers used in agricultural production). Moreover the if non-auctioned emissions permits were used to reduce these pollutants the general equilibrium costs (relative to primary costs) would be substantially higher than implied by Figure 3, since these policies serve to exacerbate the distortion in prices between the tax-favored and non-tax-favored sectors. Having said this, even if the tax-favored sector is relatively less polluting, it is still possible to generate a significant double dividend for modest levels of pollution taxes. For example, when the pollution intensity in the tax-favored sector is only 50 percent of that for the rest of the economy, a revenue-neutral tax that reduces pollution by 10 percent produces a net economic gain equal to 90 percent of primary costs in our medium MEB scenario.

D. Welfare under the Pigouvian Rule

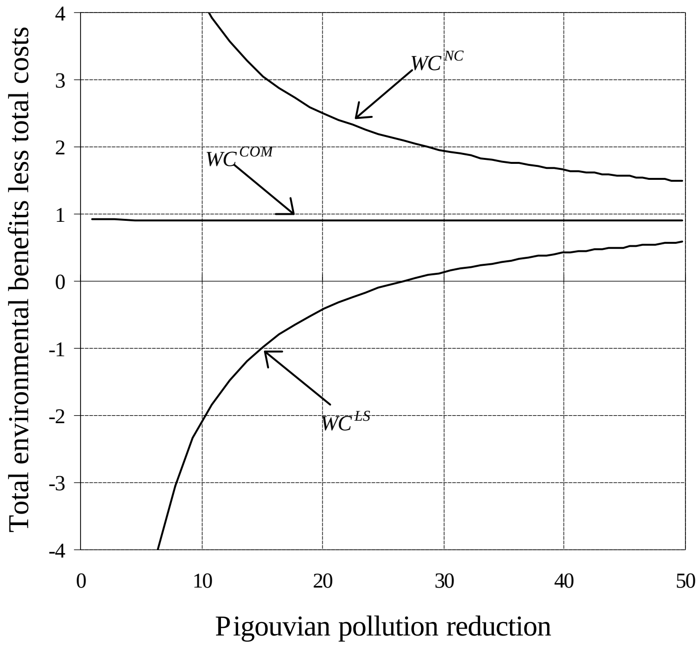
In Figure 5 we compare the overall welfare impacts of the different environmental policies (i.e. environmental benefits minus economic costs), sticking, for simplicity, with the medium MEB scenario and equal pollution intensities across sectors. We postulate different values for the marginal environmental benefit from reducing pollution, and the corresponding Pigouvian pollution reduction is shown along the horizontal axis.[34] The vertical axis shows the ratio of the general equilibrium welfare gain from this pollution reduction to the Pigouvian welfare gain (i.e. the shaded triangle in Figure 1(a)).

Again, the novel feature from this figure is the curve for the pollution tax with the strong revenue-recycling effect, W^{NC}. This curve lies above unity, while the curves for all the other policies lie below unity. That is, the general equilibrium welfare gain is higher than the Pigouvian welfare gain for this policy, and less for all other policies. Previous studies find that, even with the (normal) revenue-recycling effect, the welfare gain from Pigouvian pollution policies is at somewhat less than the Pigouvian welfare gain. In contrast, the welfare gain from the pollution tax with strong revenue recycling is more than three times the Pigouvian welfare gain for pollution reductions below 16 percent. Finally, we note again the potentially striking difference between policies that do and do not produce the (strong) revenue-recycling effect. For pollution reductions below 28 percent a pollution tax with lump-sum replacement reduces

[34] That is, the pollution reduction from imposing a tax equal to marginal environmental benefits. Marginal benefits are taken as constant, which seems a reasonable approximation for some pollutants, such as sulfur and carbon (see Burtraw et al., 1997; and Pizer, 1998).

welfare despite environmental benefits; in contrast the policy with the strong revenue-recycling effect induces a welfare gain equal to more than twice the Pigouvian welfare gain.

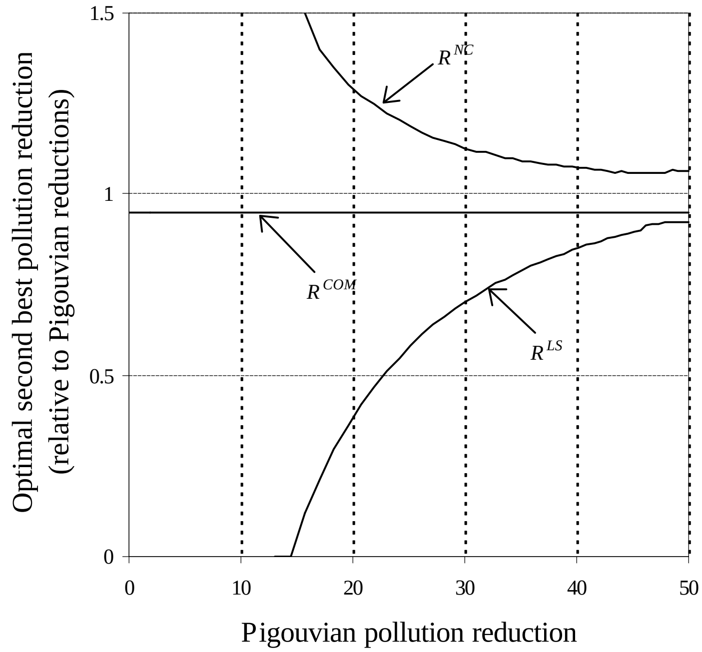
Figure 5. Welfare under the Pigouvian Rule



E. Optimal Policies

Our final diagram, Figure 6, shows the second-best optimal pollution reduction under alternative policies, expressed relative to the Pigouvian pollution reduction (for the medium MEB scenario and alternative assumptions about marginal environmental benefits). When these curves lie above (below) unity the optimal (second-best) pollution reduction is greater (less) than would be implied by a partial equilibrium analysis. As consistent with our earlier results, the optimal levels of policies differ substantially when (marginal) environmental benefits are more modest relative to (marginal) primary costs. For example when environmental benefits imply the optimal Pigouvian (or partial equilibrium) pollution reduction is 10 percent, in a general equilibrium analysis this would be zero under the tax with lump-sum replacement, 9 percent under the tax with normal revenue recycling, and 17 percent under the tax with strong revenue recycling.

Figure 6. Optimal Policies



F. Caveats

Finally, we discuss two important qualifications to the above results. First, the size of the subsidy wedge for tax-favored consumption (the height of the parallelogram in Figure 1(b)) is much more complicated than we have assumed. There may be efficiency gains from this subsidy, for example it may offset market failures due to asymmetric information in health insurance, and positive externalities to neighbors if houses are better maintained when owned rather than rented. In addition, there are a variety of regulations and taxes that raise the price of tax-favored consumption goods. These include property taxes, building codes and zoning restrictions in the housing market and occupational licensing in the health market. All of these effects reduce the overall wedge between the marginal social cost and marginal social benefit from tax-favored consumption. However what matters is the impact on the price of tax-favored goods relative to non-tax-favored goods--the price effect will tend to be offset to the extent that other regulations raise the relative price of non-tax-favored goods.

Unfortunately, the quantitative importance of these factors is often difficult to pin down (see e.g. Rosen, 1985; Pauly, 1986). Moreover, there are other factors that operate in the opposing direction. For example, housing receives additional subsidies because imputed income is not subject to tax, low-income households receive public assistance, and complementary services such as roads and schools are usually subsidized. Government programs subsidize health care for the poor and elderly. Also, these goods may confer some negative externalities, such as habitat destruction and congestion caused by housing development, and the crowding out of lower income workers from the health insurance market as prices rise in response to demand for higher quality from the better off. In short it is difficult to assess whether on balance these additional factors would increase or reduce the overall subsidy wedge for tax-favored consumption, let alone by how much.

Second, it can be difficult to pin down accurately the relative pollution intensity of the tax-favored consumption sector. For example, take the pollutants associated with energy production. Measuring the relative energy intensity of tax-favored consumption would involve estimating energy costs as a fraction of the value of health and housing output, taking account of energy used in the upstream production of all intermediate inputs used by these industries. Indeed defining the housing industry itself is tricky, for example it is not clear to what extent energy used in housing services, such as space heating and cooling, should be included. In our view it is not obvious whether tax-favored consumption is energy intensive or not relative to the production of all other final consumption goods.

5. CONCLUSIONS

This paper uses a simple numerical model to demonstrate the potential importance of tax-favored consumption for the general equilibrium welfare effects of environmental policies. When part of consumer spending is deductible from labor taxes, the tax system distorts the allocation of consumption in addition to the labor market. In this setting the welfare gain from using environmental tax revenues to reduce labor taxes can be significantly higher than implied by earlier models that do not allow for tax-favored consumption. As a result, the cost savings from using revenue-neutral environmental taxes or auctioned pollution permits over non-auctioned pollution permits can be dramatically higher than suggested by previous studies. In fact, under certain conditions, the overall costs of an environmental tax swap can easily be negative. These conditions include that at least some of the polluting input is used in the production of tax-favored goods and that the level of pollution taxes is not too high. Our results suggest that taxes on carbon, for example, might be worthwhile to implement--if set at modest levels--even in the absence of clear evidence about the benefits from limiting atmospheric accumulations of carbon dioxide.[35]

In some sense our results are paradoxical. The presence of tax-favored consumption raises the costs of the tax system and normally one would expect this to imply a smaller optimal size of government (Feldstein, 1997). In contrast we find that the optimal level of

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[35] Of course, this crucially assumes that all new sources of revenues will be used to cut distortionary taxes. Some recent public choice analyses suggest that at least part of new revenues sources are likely to be used for public spending (Becker and Mulligan, 1997; Brett and Keen, 1998). In this case the prospects for a double dividend are likely to be smaller, unless the additional spending generates social benefits well in excess of dollar outlays. On the other hand, a number of environmental taxes in Holland have been implemented in a revenue-neutral fashion. In Germany the new Social Democratic/Green Party Coalition government is proposing similar environmental tax swaps.

environmental protection through revenue-neutral taxes (or auctioned pollution permits) can be substantially *greater* in the presence of tax-favored consumption. However it is important to emphasize that this result depends entirely on our assumption of pre-existing inefficiencies within the tax system. A first-best response to these inefficiencies would be to implement direct tax reforms, such as cutting back the deductions for employer-provided health insurance and mortgage interest. Yet, probably because of opposition from adversely affected interest groups, these types of reforms have proved difficult to implement, at least in the United States. Substituting environmental taxes for personal income taxes represents a second-best response to inefficiencies within the tax system--but the distributional consequences for employees, homeowners, and so on may be less transparent.[36]

Finally, we emphasize again the preliminary nature of our findings. Future studies that improve our knowledge about key features of the market for tax-favored consumption (i.e., the demand elasticity, the relative pollution intensity, and the effect of other factors on the overall level of distortion in the market) may greatly reduce uncertainties about the general equilibrium welfare effects of (revenue-neutral) environmental taxes. The results may also have less relevance for other countries. For example, in Britain mortgage interest tax relief has almost been phased out, and most people rely on the National Health Service rather than (subsidized) private health insurance.

[36] On the other hand environmental taxes or auctioned pollution permits may also invoke a lot of opposition from the affected industries.

APPENDIX A
Formal Derivation of Welfare Effects

Here we provide a formal derivation of the welfare effects discussed in Section 2 for the pollution tax with lump-sum replacement and with the strong revenue-recycling effect. For simplicity we focus on incremental policy changes (rather than the non-marginal changes shown in Figure 1). All variables are as defined in the text.

Suppose household utility is:

$$U(X, Y, \overline{L} - L) - \phi(Z) \tag{A1}$$

and the household faces the budget constraint:

$$(1 - t_N) p_X(\tau) X + p_Y(\tau) Y = (1 - t_N - t_C) L + G \tag{A2}$$

where the prices of goods depend on the pollution tax τ.[37] Households choose X, Y and L to maximize (A1) subject to (A2), taking Z as given. The solution to this problem is the (uncompensated) demand and labor supply functions. These functions can be expressed as follows:

$$X(\tau, t_N, t_C, G), \qquad Y(\tau, t_N, t_C, G), \qquad L(\tau, t_N, t_C, G) \tag{A3}$$

The derived demand for the polluting good can also be expressed as a function of the exogenous variables:

$$Z(\tau, t_N, t_C, G) \tag{A4}$$

Substituting (A3) and (A4) into (A1) gives:

$$V(\tau, t_N, t_C, G) - \phi(Z(\tau, t_N, t_C, G)) \tag{A5}$$

where V is indirect utility from non-environmental goods. From Roy's identity

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[37] Since firms are competitive and supply curves are perfectly we do not need to explicitly model firm behavior. The tax on the polluting input is fully passed on to consumers in the form of higher product prices.

$$\frac{\partial V}{\partial \tau} = -\lambda Z \qquad \frac{\partial V}{\partial t_N} = -\lambda (L - X) \qquad \frac{\partial V}{\partial t_C} = -\lambda L \qquad \frac{\partial V}{\partial G} = \lambda \tag{A6}$$

where λ is the marginal utility of income and we have normalized p_X to unity.

(i) Pollution tax with lump-sum replacement

Differentiating (A5) with respect to τ and holding t_N and t_C constant, and using (A6), gives:

$$\frac{1}{\lambda}\frac{dV}{d\tau} = -Z + \frac{dG}{d\tau} - \frac{\phi'}{\lambda}\frac{dZ}{d\tau} \tag{A7}$$

where

$$\frac{dZ}{d\tau} = \frac{\partial Z}{\partial \tau} + \frac{\partial Z}{\partial G}\frac{dG}{d\tau} \tag{A8}$$

The government budget constraint is:

$$G = (t_N + t_C)L - t_N X + \tau Z \tag{A9}$$

Totally differentiating (A9) holding t_N and t_C constant, we can obtain:

$$\frac{dG}{d\tau} = (t_C + t_N)\frac{dL}{d\tau} - t_N \frac{dX}{d\tau} + Z + \tau \frac{dZ}{d\tau} \tag{A10}$$

where the the first two price coefficients on the right-hand side are analogous to (A8). From (A7) and (A10)

$$\frac{1}{\lambda}\frac{dV}{d\tau} = \left(\frac{\phi'}{\lambda} - \tau\right)\left(-\frac{dZ}{d\tau}\right) - t_N \frac{dX}{d\tau} + (t_C + t_N)\frac{dL}{d\tau} \tag{A11}$$

The left-hand side of this expression is the general equilibrium (marginal) welfare effect (in dollars) and the terms in the right hand-side correspond to the Pivouvian welfare gain, the subsidy-interaction effect, and the tax-interaction effect discussed in Section 2.

(ii) Pollution tax with Strong Revenue-Recycling Effect

The difference between this policy and the previous one is that the extra revenue, $dG/d\tau$, is used to reduce t_N rather than increase the lump-sum transfer. Thus, the welfare effect is equal to that in (A11) plus:

$$\frac{1}{\lambda}\left\{-\frac{\partial V}{\partial G}+\frac{\partial V}{\partial t_N}\left(-\frac{dt_N}{dG}\right)\right\}\frac{dG}{d\tau} \tag{A12}$$

that is, we subtract off the gain in utility from increasing G and add on the gain in utility from reducing t_N. Totally differentiating (A9) with respect to t_N and G we can obtain (setting $\tau=0$)

$$\frac{dt_N}{dG}=\left\{L+t\frac{dL}{dt_N}-t_N\frac{dX}{dt_N}-X\right\}^{-1} \tag{A13}$$

where $t=t_C+t_N$,

$$\frac{dL}{dt_N}=\frac{\partial L}{\partial t_N}+\frac{\partial L}{\partial G}\frac{dG}{dt_N} \tag{A14}$$

and similarly for dX/dt_N. Substituting (A13) and (A6) in (A12) gives:

$$MEB^N\frac{dG}{d\tau} \tag{A15}$$

where

$$MEB^N=\frac{-t\dfrac{dL}{dt_N}+t_N\dfrac{dX}{dt_N}}{L-X+t\dfrac{dL}{dt_N}-t_N\dfrac{dX}{dt_N}} \tag{A16}$$

MEB^N is the MEB of the non-comprehensive tax; that is, the welfare loss from raising an extra dollar of revenue from increasing t_N. The numerator in (A16) is the welfare loss in the labor market from an incremental increase in t_N (i.e., the wedge between the gross and net wage multiplied by the reduction in labor supply) plus the welfare loss from the increase in tax-favored consumption (i.e., the subsidy wedge between the supply and demand price for X

times the increase in *X*). The denominator is the additional revenue from an incremental increase in t_N (from differentiating $(t_C + t_N)L - t_N X$).

Differentiating (A9) with respect to t and *G* and substituting in (A15) gives:

$$MEB^N \left\{ Z + t \frac{dL}{d\mathrm{t}} - t_N \frac{dX}{d\mathrm{t}} \right\} \tag{A17}$$

when $\mathrm{t}=0$. This is the (marginal) strong revenue-recycling effect. It equals the MEB times the revenue raised by increasing the pollution tax, net of the reduction in labor tax revenue and the implicit change in subsidy payments for *X*.

APPENDIX B
Deriving a Formula for the MEB

From the Slutsky equations:

$$\frac{\partial L}{\partial t_N} = \frac{\partial L^H}{\partial t_N} - \frac{\partial L}{\partial G}(L - X); \qquad \frac{\partial X}{\partial t_N} = \frac{\partial X^H}{\partial t_N} - \frac{\partial X}{\partial G}(L - X) \tag{B1}$$

where "*H*" denotes a Hicksian (compensated) price effect. From (B1), (A14) and the analogous expression for dX/dt_N, and (A16):[38]

$$MEB^N = \frac{\frac{t}{L}\frac{\partial L^H}{\partial(1-t)} - s_X \frac{t_N}{X}\frac{\partial X^H}{\partial(1-t_N)}}{1 - \frac{t}{L}\frac{\partial L}{\partial(1-t)} - s_X\left\{1 - \frac{t_N}{X}\frac{\partial X}{\partial(1-t_N)}\right\}} \tag{B2}$$

where $s_X = X/L$. Finally, we can obtain equation (2.2) by substituting the following formulas for the Marshallian and Hicksian labor supply elasticities (ε_L^M and ε_L^H), and the Marshallian and Hicksian own price elasticities of demand for *X* (η_X^M and η_X^H), expressed as positive numbers:

$$\varepsilon_L^M = \frac{\partial L}{\partial(1-t)}\frac{1-t}{L}; \qquad \varepsilon_L^H = \frac{\partial L^H}{\partial(1-t)}\frac{1-t}{L}; \qquad \eta_X^M = -\frac{\partial X}{\partial(1-t_N)}\frac{1-t_N}{X}; \tag{B3}$$

$$\eta_X^H = -\frac{\partial X}{\partial(1-t_N)}\frac{1-t_N}{X}$$

38 Note that $\frac{\partial L}{\partial t_N} = -\frac{\partial L}{\partial(1-t)}$; $\frac{\partial X}{\partial t_N} = -\frac{\partial X}{\partial(1-t_N)}$ and the same applies for the Hicksian price effects.

APPENDIX C

The Relationship between the Elasticity of Taxable Income and Key Parameters in our Analysis

Several recent studies have estimated the (compensated) elasticity of taxable income with respect to a change in tax rates, using time series data on individuals' personal income tax returns (e.g. Feldstein, 1995b). The first studies found values for this elasticity in the range of 1 to 1.5, although the recent studies using 1990's data are somewhat lower (Carroll, 1998, Table 1). In our model, taxable income corresponds to labor income minus exemptions for spending on *X*. Therefore this elasticity would be defined by:

$$\varepsilon_{TI}^{H} = \frac{\partial (L - X)^{H}}{\partial (1 - t_C - t_N)} \frac{1 - t_C - t_N}{L - X} \qquad \text{(C1)}$$

Some manipulation gives:[39]

$$\varepsilon_{TI}^{H} = \frac{\partial L^{H}}{\partial (1 - t_C - t_N)} \frac{1 - t_C - t_N}{L} \frac{1}{1 - s_X} + \frac{\partial X^{H}}{\partial t_N} \frac{1 - t_N}{X} \frac{1 - t_C - t_N}{1 - t_N} \frac{s_X}{1 - s_X} \qquad \text{(C2)}$$

Substituting from (B3) gives:

$$\varepsilon_{TI}^{H} = \frac{1}{1 - s_X} \left\{ \varepsilon_{L}^{H} + \frac{1 - t_C - t_N}{1 - t_N} s_X \eta_{X}^{H} \right\} \qquad \text{(C3)}$$

Our parameter values would imply ε_{TI}^{H} = 0.41, 0.64 and 0.93 in our low, medium and high MEB scenarios. These are below the estimates of ε_{TI}^{H} that Feldstein (1995a) used to calculate the MEB. To the extent that this difference is due to higher values of s_X and η_{X}^{H}, rather than higher labor supply responses, then we may have understated the difference between the strong and normal revenue-recycling effects, and the potential for a double dividend from environmental tax reform. However Feldstein is careful to emphasize that the estimates of ε_{TI}^{H} are preliminary, and may be "too high" for our purposes. For example, they are based on a sample of married, higher income taxpayers that may be more responsive to tax changes than the average taxpayer. In addition, changes in taxable income reflect certain types of tax-deductible spending such as charities that we exclude from our analysis.

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39 Note that $\frac{\partial (p_X X)}{\partial (1 - t_C - t_N)} = -p_X \frac{\partial X}{\partial t_N}$.

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