Non-Homothetic Preferences and the Non-Environmental Effects of Environmental Taxes

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ABSTRACT

We show that, if the utility function is non-homothetic, environmental taxes can have positive non-environmental effects. These effects are illustrated with specific reference to taxes on gasoline and tobacco, in the context of a computational model. We also clarify the relationship between the "double dividend" (associated with a marginal change from a tax system with low reliance on environmentally motivated taxes) and the situation in which the optimal environmental tax rate is greater than the Pigouvian tax rate. These two situations are generated by rather similar combinations of parameters.

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1. Introduction

From the perspective of the policymaker, the case for environmental taxes would be strengthened considerably, if either of two situations occurs. In the first situation, a small increase in an environmental tax, offset by a reduction in other taxes, leads to an efficiency gain, even if the environmental benefits are ignored. If this situation exists, then policymakers could proceed confidently with such taxes, at least at modest levels. This situation is commonly called a “double dividend”. In the second situation, the second-best-optimal environmental tax rate is greater than the first-best Pigouvian tax rate. If this situation exists, then policymakers would be encouraged to err on the high side when choosing the size of environmental taxes.[1]

These two situations are related, but not identical. The first is concerned with incremental tax reform, around a tax system with a low level of environmentally motivated taxes. The second situation is concerned with marginal changes in the neighborhood of the first-best Pigouvian tax rate. In this paper, we examine the conditions that are necessary for each of these situations to occur.

In the 1980s and early 1990s, authors such as Terkla (1984), Pearce (1991), and Oates (1993) were optimistic about the non-environmental effects of environmental taxes. However, later papers such as Bovenberg and de Mooij (1994), Bovenberg and van der Ploeg (1994), Parry (1995), and Bovenberg and Goulder (1997), cast doubt on whether environmental taxes can have positive non-environmental effects, except in special cases.

The earlier studies focused on the "revenue-recycling effect": By itself, the reduction in another tax, such as the income tax, can lead to an efficiency gain. However, the increase in the environmentally motivated tax will raise the prices of pollution-intensive goods. These price increases offset the reduction in labor-market distortion: The incentive to work can fall, even when the reduction in the labor tax is accounted for. According to Bovenberg and de Mooij (B-de M, (1994), "…[I]n the presence of preexisting distortionary taxes, the optimal pollution tax typically lies below the Pigovian tax...". Much of the reasoning of B-de M is echoed in a number of other papers, some of which have also challenged the possibility of a double dividend.[2]

One reason for the strong result of B-de M is that they assume an initial tax system that is optimal, in the absence of environmental considerations. Some authors have developed alternative models, under which the initial tax system is *not* optimal, even in the absence of pollution. In some cases, these models are capable of finding a double dividend, as well as an optimal environmental tax above the Pigouvian rate. For example, Bovenberg and Goulder (1997) build a model in which the initial tax system is inefficient in its treatment of capital and labor. They find non-environmental benefits from environmental taxes (but only for unusual combinations of parameters and policies). Parry and Bento (2000) assume an initial tax system that is inefficient because of tax preferences for certain consumption goods, such as housing and medical care. In their model, a revenue-neutral emissions tax can also produce non-environmental benefits.

The models of Bovenberg-Goulder and Parry-Bento are capable of finding non-environmental benefits, because of assumptions regarding the configuration of *initial tax rates*. In addition, the *structure of preferences* can be such that environmental taxes have non-environmental benefits. If environmental quality is not separable from leisure in the utility function, and a better environment brings forth more labor supply, then environmental taxes can generate positive non-environmental effects. See Schwartz and Repetto (1997) and Williams (1999).

In this paper, we use a small-scale computational general equilibrium model to analyze the relationship between the preference structure and the non-environmental effects of environmental taxes. We use a simulation model tailored to the assumptions of B-de M, including separability, but we allow for non-homothetic preferences for goods.

We verify numerically the analytical results of B-de M: When preferences are homothetic and separable, (1) there is no double dividend when we begin from a position of uniform taxation, and (2) the optimal tax rate is only greater than the Pigouvian tax rate when the labor-supply elasticity is negative.[3] Then we show that with non-homotheticity, environmentally motivated taxes on gasoline and cigarettes can generate non-environmental benefits. Moreover, we show that this result prevails over a wide range of plausible parameter values.

We also analyze the relationship between the situations in which (a) there is a double dividend starting from a uniform tax, and (b) the optimal environmental tax is greater than the Pigouvian tax. We find that they occur together (or neither obtains) if the derivative of labor supply with respect to a balanced-budget change in the environmental tax has the same sign at a zero environmental tax and at the Pigouvian tax.

Much of this literature deals with taxes on "dirty goods", for which production or consumption creates an externality. Our simulations also involve dirty-goods taxes. Similar results occur in a model in which emissions are taxed directly. (See Kim (2000).)[4]

2. Environmental Taxes, With and Without Homothetic Utility

A representative household derives utility from consumption of a clean good (*C*), a dirty good (*D*), leisure (*V*), a public good (*G*), and environmental quality (*E*). Throughout this paper, we assume that the public good and environmental quality are weakly separable from the other goods, so we may write:

$$U = u(H(C, D, V), G, E)\,. \tag{1}$$

Following B-de M, we assume that the technology is linear, with labor (*L*) the only factor of production. Defining units so that one unit of labor can produce one unit of *C*, *D*, or *G*, the production constraint becomes

$$L = C + D + G\,. \tag{2}$$

The household is endowed with one unit of time, so $L = 1 - V$. Goods are produced competitively, so there are no economic profits. In this setting, the gross-of-tax wage and net-of-tax goods prices may all be normalized to unity.

We assume that environmental quality is affected only by consumption of the dirty good, and that the marginal environmental damage is constant in utility terms. We thus specialize (1) to

$$U = H(C, D, V) - \pi D + G\,, \tag{1'}$$

where π is the marginal damage parameter. Since we consider experiments in which public expenditure is held constant, we can enter G additively without loss of generality.

As in B-de M, we treat the clean good as untaxed, so the available tax instruments are taxes on the dirty good and labor.[5] In this static model, a labor tax is equivalent to a uniform tax on the two consumption goods. A positive t_D thus implies a differential tax on the dirty good relative to the clean good. For convenience, we include a lump-sum income term, Z, in the household's budget constraint.[6] The budget constraint is

$$(1-t_L)L + Z = (1+t_D)D + C \, . \tag{3}$$

The government's budget constraint is

$$t_L L + t_D D = G \, . \tag{4}$$

Household maximization of $H(\cdot)$ subject to (3) yields demand functions for D and C, and a labor-supply function. Substituting these into (1') leads to an indirect utility function $W((1+t_D),(1-t_L),Z,\pi,G)$. Although $W(\cdot)$ incorporates the externality and the public good, those effects are assumed to be exogenous to household decisions.

We now consider the optimal choice of t_D and t_L, maximizing $W(\cdot)$ subject to (4), with π and G fixed and $Z = 0$. If lump-sum taxes were available, the Pigouvian tax on the dirty good would be $t_D^{pig} = \pi / H_C$, which is the marginal environmental damage expressed in units of the numeraire (H_C is the partial derivative of $H(\cdot)$ with respect to C).

Bovenberg and Goulder (2002) show that, without lump-sum taxes, the following holds at the optimal t_D and t_L:

$$\frac{t_D}{1+t_D} = \left(\frac{\varepsilon_{CL} - \varepsilon_{DL}}{\varepsilon_{CD} - \varepsilon_{DD}}\right)\left(\frac{t_L}{1-t_L}\right) + \frac{t_D^{pig}/\eta}{1+t_D}, \tag{5}$$

where ε_{ik} is the compensated elasticity of demand for commodity *i* with respect to the price of commodity *k*, and $\eta = \mu/H_C$, where μ is the Lagrange multiplier for the government budget constraint (i.e., the utility cost of raising a dollar of government revenue).[7] The ratio η is commonly referred to as the marginal cost of public funds.

Equation (5) shows that the optimal tax on the dirty good can be separated into a "Ramsey" component, based on the theory of optimal commodity taxation in the absence of externalities, and an externality-correcting component. The Ramsey component is positive if and only if $\varepsilon_{CL} > \varepsilon_{DL}$ (*i.e.*, if the dirty good is more complementary with leisure). An analogous condition was first discussed by Corlett and Hague (1953).

Thus far, we have placed no special restrictions on $H(\cdot)$. B-de M assume that leisure is weakly separable from goods and that the goods subutility function is homothetic. In the B-de M case, $\varepsilon_{CL} = \varepsilon_{DL}$, so the Ramsey term vanishes. It follows that the optimal t_D is the Pigouvian rate divided by η, which here specializes to

$$\eta = \left(1 - \frac{t_L}{(1-t_L)}\varepsilon_{LL}^U\right)^{-1}, \tag{6}$$

where ε_{LL}^{U} is the uncompensated wage elasticity of labor supply. Thus, at the optimum in the B-de M case, $t_D < t_D^{pig}$ as long as $\varepsilon_{LL}^{U} > 0$.

Under these assumptions, increasing t_D reduces the real wage by increasing the price of the dirty good, even when t_L is adjusted to hold revenue constant. Thus, a revenue-neutral increase in t_D increases the labor-supply distortion. The marginal cost of increased distortion balances the marginal benefit from improved environmental quality at a tax rate less than the Pigouvian rate.

Another useful expression may be obtained by incorporating the government's budget constraint (4) into the household's indirect utility function, $W(\cdot)$, and maximizing utility as a function of t_D alone. This approach has the advantage of telling us something about the welfare effects of changes in t_D at points away from the second-best optimum. Defining $\tilde{W}(t_D; Z, \pi, G)$ as

$$\tilde{W}(t_D; Z, \pi, G) = W((1+t_D), (1-t_L(t_D)), Z, \pi, G), \tag{7}$$

we show in the Appendix that

$$\frac{d\tilde{W}/dt_D}{H_C} = -\frac{\pi}{H_C}\frac{dD}{dt_D} + \left(t_D \frac{dD}{dt_D} + t_L \frac{dL}{dt_D}\right). \tag{8}$$

Equation (8) is a decomposition of the welfare effect of a change in t_D (in units of the untaxed clean good). The first part of the right-hand side of equation (8) is the beneficial effect on the environment from a tax-induced reduction in *D*. The second (in parentheses) works through balanced-budget changes in quantities of taxed items, which have first-order effects on consumer welfare. We will refer to this as the second dividend.

Equation (8) shows the key role of dL/dt_D, the effect on labor supply of a balanced-budget change in t_D, in determining the welfare effects of changes in the environmental tax. (An expression for dL/dt_D is derived in the Appendix.) In the B-de M case, $dL/dt_D = 0$ at $t_D = 0$, which implies no double dividend, even when starting from a zero environmental tax. At the Pigouvian rate, the right-hand side of (8) simplifies to $t_L\, dL/dt_D$, and $d\tilde{W}/dt_D$ has the opposite sign of the uncompensated wage elasticity of labor supply in the B-de M case. Without homotheticity, however, dL/dt_D also depends on complementarity or substitutability between the dirty good and leisure.

To summarize, non-homotheticity creates the potential for a double dividend, or for the optimal tax to exceed the Pigouvian tax, if the dirty good is more complementary with leisure than is the clean good. Maintaining weak separability between goods and leisure, the good more complementary to leisure is the one with the smaller expenditure elasticity of demand (Deaton (1981)). Later in this paper, we present evidence that the expenditure elasticity of demand is indeed smaller than average for gasoline and cigarettes, which are two goods for which taxes have been motivated in terms of correcting environmental externalities. Thus, for some important environmentally motivated taxes, the conditions exist for double dividends, and for the optimal tax rate to exceed the Pigouvian tax rate.[8]

3. The Simulation Model

We specify $H(\cdot)$ as a nested constant-elasticity-of-substitution (CES) utility function. The labor/leisure choice is represented by the outer nest of the utility function, which is defined over leisure and consumption of a composite good Q:

$$H = \left[\beta^{\frac{1}{\sigma}} V^{\frac{\sigma-1}{\sigma}} + (1-\beta)^{\frac{1}{\sigma}} Q^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} , \qquad (9)$$

where σ is the elasticity of substitution between leisure and the composite good. The "weighting parameter," β, is used in calibrating the model to particular elasticity values.

We introduce non-homotheticity by using a "generalized CES" subutility function for goods, in which utility is only generated when consumption is greater than some pre-specified level, which can be interpreted as a "minimum consumption requirement."[9] C^* and D^* are the "requirements" for the clean good and the dirty good. The subutility function is

$$Q = \left[\alpha^{\frac{1}{\nu}} (D-D^*)^{\frac{\nu-1}{\nu}} + (1-\alpha)^{\frac{1}{\nu}} (C-C^*)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} , \qquad (10)$$

where ν is the elasticity of substitution between discretionary consumption of the dirty good $(D-D^*)$ and discretionary consumption of the clean good $(C-C^*)$. An ordinary CES utility function is homothetic with respect to the origin, but the generalized CES function is homothetic with respect to the displaced origin, (C^*, D^*).

Indirect utility is

$$W\left[(1+t_D),(1-t_L),Z,\pi,G\right]= \left[(1-t_L)-(1+t_D)D^*-C^*+Z\right]\big/P^*-\pi D((1+t_D),(1-t_L),Z)+G, \qquad (11)$$

where $P^*=[\beta(1-t_L)^{(1-\sigma)}+(1-\beta)P_Q^{(1-\sigma)}]^{1/(1-\sigma)}$ is the ideal price index for the outer nest of the utility function, and $P_Q=[\alpha(1+t_D)^{(1-\nu)}+(1-\alpha)]^{1/(1-\nu)}$ is the ideal price index for goods. Utility is the household's real full income less that committed to required commodities, minus the effect of environmental damage, plus utility from public goods.

The demand function for the dirty good and the labor-supply function are

$$D((1+t_D),(1-t_L),Z)=\frac{\alpha((1-t_L)L-(1+t_D)D^*-C^*+Z)}{(1+t_D)^{\nu}P_Q^{(1-\nu)}}+D^* \qquad (12)$$

$$L((1+t_D),(1-t_L),Z)=1-\frac{\beta((1-t_L)-(1+t_D)D^*-C^*+Z)}{(1-t_L)^{\sigma}P^{*(1-\sigma)}}. \qquad (13)$$

Setting $D^* = C^* = 0$ gives the homothetic case, with both expenditure elasticities equal to one. In our simulations, we usually set $C^* = 0$ and $D^* > 0$, so that the expenditure elasticity of demand for the dirty good is less than one. Thus, the dirty good is relatively complementary with leisure. In such cases, as shown in the Appendix (equation (A11)), dL/dt_D is definitely positive at $t_D = 0$, regardless of the sign of the uncompensated labor-supply elasticity. It follows from equation (8) that the second dividend will *always* be positive at $t_D = 0$ when $D^* > 0$ and $C^* = 0$. The intuition is the same as that of Corlett and Hague; in this case, the dirty good is less substitutable with leisure, so taxing it can improve the efficiency of the tax system.[10] Viewed another way, the tax on the dirty good is now relatively less distorting because part of it falls on D^*. It is as if a portion of the tax on D is a lump-sum tax. Equation (8) and equation (A11) together imply that, for given values of π and the price elasticity of demand for the dirty good, the second dividend at $t_D = 0$ is increasing in the compensated wage elasticity of labor supply, and decreasing in the expenditure elasticity of demand for the dirty good.

4. Simulations of Environmental Taxes in a Model with Non-Homothetic Utility

We choose D^* to calibrate to the desired value of the expenditure elasticity of demand for the dirty good. We also calibrate to a set of values for the labor-supply elasticities. Based on Killingsworth (1983), Heckman (1993), and Blundell and MaCurdy (1999), we choose 0.15 for our central-case value of the uncompensated labor-supply elasticity, and -0.15 for the total-income elasticity of labor supply. (However, there is great variation among the estimates in the labor-supply literature, especially in studies of women. Therefore, we analyze the sensitivity of the model over a range of elasticity values.)

In the base case in all of our simulations, we set taxes equal to 40 percent of output. We do this by choosing a base level for t_D and adjusting t_L to achieve the revenue target.[11] In the revised case, a portion of the labor tax is replaced with an increased tax on the dirty good, in a revenue-neutral manner. We solve numerically for the t_L associated with any particular t_D, and then use (11) to calculate equivalent-variation measures of welfare change for changes in t_D, as explained in the Appendix.

4.1. Gasoline Taxes

Parry and Small (2002) provide a thorough review of the literature on gasoline externalities and vehicular travel. They suggest that the Pigouvian tax on gasoline in the United States is about 74 cents per gallon, based on data for air pollution, accidents, and congestion. Based on this information, we choose a value for π (the marginal damage parameter) of 1.0. For our central-case parameters, we choose values consistent with the literature discussed in Parry and Small: 0.02 for the expenditure share for gasoline, -0.6 for the gasoline demand elasticity, and 0.7 for the gasoline expenditure elasticity. Using these parameters, we calculate that the optimal tax is about 120% of the Pigouvian tax.[12] This result holds even though our model verifies the B-de M result that the optimal tax rate is less than the Pigouvian rate in the homothetic case.

Of course, this result depends on the assumption that the expenditure elasticity for gasoline is less than one. The empirical evidence in support of this assumption is convincing, although the precise value of the expenditure elasticity is uncertain (as are the precise values of all of the parameters). Another parameter that plays a crucial role in determining the simulation results is the labor-supply elasticity. In Figure 1, we show the results of a large number of simulations, for different values of the expenditure elasticity for gasoline and the labor-supply elasticity. We allow the expenditure elasticity to vary from 0.5 to 1.2.[13] The top part of this range includes higher values than would be indicated by most empirical studies of gasoline demand. We include these values because they illustrate some important concepts. Thus, although this discussion is carried out in the context of gasoline, the results in Figure 1 have more general relevance.

We define θ as the ratio of the optimal tax to the Pigouvian tax. In Figure 1, we consider labor-supply elasticities of 0.05, 0.15, and 0.25. Since we do not consider any negative values for this elasticity, the theory dictates that θ should be less than one when the expenditure elasticity of the dirty good is assumed to be 1.0. Indeed, in this homothetic case, θ is about 96.9% for an uncompensated labor-supply elasticity of 0.05, about 90.3% for an elasticity of 0.15, and about 83.8% for an elasticity of 0.25. Higher values of the labor-supply elasticity are associated with lower values of θ, because the deviation from uniform taxation is more distorting when the labor-supply elasticity is larger.

When the expenditure elasticity is lower, θ rises. For a labor-supply elasticity of 0.05, θ exceeds one when the expenditure elasticity is 0.94 or less. When the labor-supply elasticity is 0.25, θ exceeds one when the expenditure elasticity is 0.85 or less. Our reading of the literature is that the expenditure elasticity for gasoline is probably no more than 0.8. For values of the expenditure elasticity less than 0.8, our simulations suggest that θ is at least about 1.09, and can range as high as 1.5 or 2.0 or even higher.

It is interesting to note that the effect of the labor-supply elasticity on θ is different for low values of the expenditure elasticity than for high values. We have seen that, for higher values of the expenditure elasticity, θ is larger when the labor-supply elasticity is smaller. However, when the expenditure elasticity falls below about 0.79, θ is larger when the labor-supply elasticity is larger. This result gets us back to the intuition of Terkla (1984), Pearce (1991), and Oates (1993), that revenue-recycling gains ought to push in the direction of higher environmental taxes when other taxed goods are more elastically supplied or demanded. B-de M showed that this intuition is not correct in general. However, it is correct if the expenditure elasticity of the dirty good is sufficiently small (the critical value depending on other parameters of the model). When the expenditure elasticity is smaller, the dirty good tax acts more like a lump-sum tax. Replacing a labor tax with a tax that is much like a lump-sum tax is more beneficial when the labor supply elasticity is larger.

Earlier in this section, we mentioned some combinations of parameters that were sufficient for θ to be greater than one (*i.e.*, for the optimal environmental tax rate to be greater than the Pigouvian tax rate). In Figure 2, we show the critical values of the expenditure elasticity for gasoline below which θ is greater than one, for various values of the labor-supply elasticity and the own-price elasticity of demand for gasoline. As before, we show the results of simulations that cover a wide range of elasticity combinations. Thus, although this discussion is couched in terms of the gasoline market, the results may be relevant for a number of goods that are associated with negative externalities.

Since we restrict our attention to positive labor-supply elasticities, all of the critical values of the expenditure elasticity shown in Figure 2 are less than one. In the range of parameters shown in Figure 2, the labor-market distortion caused by taxes on the dirty good is larger when the labor-supply elasticity is larger. Therefore, as we move to larger labor-supply elasticities, the expenditure elasticity must be smaller, if θ is to exceed unity.

In Figure 2, we consider own-price elasticities of demand for the dirty good of –0.3, –0.6, and –0.9. These values span most of the empirical estimates of the own-price elasticity of demand for gasoline. When the demand elasticity is small in absolute value, relatively less damage is done by an increase in the gasoline tax, all else equal. Therefore, for any given value of the labor-supply elasticity, the critical value of the gasoline expenditure elasticity is larger when the own-price elasticity of demand for gasoline is smaller in absolute value. In other words, when the demand elasticity of the dirty good is small, it does not take a very great deviation from homotheticity to guarantee that θ is greater than one.

4.2. Cigarette Taxes

The economic analysis of tobacco products is similar in many respects to the analysis of gasoline. Each is associated with negative externalities. The expenditure elasticity is almost certainly less than one in each case, so that each would have a double dividend. The own-price elasticity is also less than one. In fact, the parameter combinations that we would assign for tobacco are remarkably similar to the parameter combinations discussed above, for the case of gasoline. One difference is that the expenditure share is about 0.02 for gasoline, but only about 0.01 for tobacco products. However, the expenditure share has very little effect on the size of the optimal tax rate.

Gruber (2001) discusses the tobacco market and public policy toward tobacco. The standard model for assessing tobacco involves "rational addiction". In the rational-addiction model, negative externalities are the only justification for tobacco taxes. Our reading of this literature suggests that the correct value of π for tobacco may be in the range of 0.5 to 1.0. Thus, if we accept the analysis of gasoline provided by Parry and Small (2002), discussed above, the correct value of π that emerges from a rational-addiction analysis of tobacco is probably less than the correct value of π for gasoline.

However, Gruber and Köszegi (2002) present a novel argument under which the correct value of π for tobacco might be far higher than suggested by the rational-addiction model. Their model involves consumers who discount the future in a time-inconsistent way. If time-inconsistency is incorporated into the model, Gruber and Köszegi show that the correct value of π can easily reach very high values, of 2 or even more.

Since we use a static model, we cannot precisely duplicate all of the features of the analysis of Gruber and Köszegi. Still, it is interesting to see the results that emerge from our model when we use higher values of π. For the simulation results reported below, we will assume that the expenditure elasticity of the dirty good is 0.7, its expenditure share is 0.01, and the own-price elasticity of demand is –0.6. (See Gruber (2001).)

When the labor-supply elasticity is 0.05, θ is about 1.16 when $\pi = 1$, rising slightly to about 1.20 when $\pi = 2.5$. When the labor-supply elasticity is 0.15, θ is about 1.21 when $\pi = 1$, and increases to about 1.29 when $\pi = 2.5$. These and other (unreported) simulation results indicate that θ is not very sensitive to the value of π, for most plausible values of the other parameters.[14]

These results imply that the optimal t_D increases more than proportionately with increases in π, which may seem surprising, since marginal revenue-recycling gains are expected to fall with successive increments of the environmental tax. We note, however, that when π is large, the simulations involve large changes in relative prices compared with the base at which we calibrate the model. These large changes in relative prices lead to endogenous changes in elasticities. For example, under our specification, as the price of the dirty good rises, the required portion of consumption (D^*) becomes a larger portion of total consumption. Since the required portion is completely inelastic, the price and expenditure elasticities fall. These effects push in the direction of higher optimal taxes.[15]

Because of the issue mentioned in the previous paragraph, we do not want to overemphasize the results of the sensitivity analysis with respect to π. Each simulation is based on a particular set of elasticity values, but those elasticities can change greatly when prices change by a large amount. Thus, the interpretation of the results becomes more challenging as π increases. This is an aspect of simulation modeling that will require increasing attention in the future.

4.3. The Double Dividend and the Optimal Environmental Tax

Earlier in this paper, we drew the distinction between the double dividend (where a marginal increase in the environmental tax leads to a welfare gain, even when environmental quality is ignored) and the situation in which the optimal environmental tax rate is greater than the first-best environmental tax rate. Equation (8) implies that whether a double dividend exists (starting from uniform taxation) depends on the sign of the derivative of labor supply with respect to a balanced-budget change in the environmental tax. Equation (8) also implies that whether the optimal environmental tax rate is higher than the first-best Pigouvian tax rate depends on the sign of the very same derivative, evaluated at a different point. Equation (A11) shows that a necessary and sufficient condition for a double dividend to exist at $t_D = 0$ is that the expenditure elasticity of the dirty good be less than 1. If the wage elasticity of labor supply is nonnegative, the same condition is necessary, but not sufficient, for the optimal environmental tax rate to exceed the Pigouvian tax rate (i.e., $\theta > 1$). Thus, while a double dividend does not necessarily imply that θ exceeds 1, the two situations occur together for many combinations of parameters. As Figure 2 shows, the expenditure elasticity need only be less than 1 by a modest amount, especially if labor supply and the demand for the dirty good are not very elastic. For additional discussion, see Kim (2000).

5. Conclusion

A number of studies have suggested that environmental taxes can only generate positive non-environmental effects in unusual circumstances. However, a great number of these papers assume that the utility function for goods is homothetic and separable from the utility derived from leisure. In the simplest model, in which (1) labor is the only productive factor, (2) there is one “clean” good and one “dirty” good, and (3) the effects of environmental pollution are separable from the rest of utility, homotheticity and separability will guarantee that there is no double dividend. Also, the optimal dirty-good tax rate will be below the Pigouvian tax rate, unless the labor-supply elasticity is negative.

We use a static computational general-equilibrium model that incorporates the assumptions listed in the previous paragraph. When we assume that utility is homothetic, we confirm the earlier results. For our preferred parameters, the optimal tax rate on the dirty good is in the vicinity of 90 percent as great as the first-best Pigouvian tax rate. However, these results can be reversed when we allow for non-homotheticity of goods consumption (while maintaining the separability assumptions). A double dividend then occurs for a small tax on the dirty good, whenever the expenditure elasticity of demand for the dirty good is less than unity. In fact, expenditure elasticities *are* less than one for many goods that are thought to involve external costs. Also, in such cases, the optimal tax rate on the dirty good can be substantially larger than the marginal environmental damage. We illustrate these concepts with simulations based on parameters that are appropriate for gasoline and cigarettes. Each of these commodities is subject to environmentally motivated taxes, and each has an expenditure elasticity less than one. Our simulations suggest that, for reasonable sets of parameters, the optimal taxes on these commodities could be at least 20% greater than the Pigouvian taxes. For some parameter combinations, the optimal environmental tax can exceed the Pigouvian tax by 100% or even more.

Some additional *caveats* are in order, however. Commodity taxes clearly have distributional effects when individuals have different productive capacities and preferences are non-homothetic. Taxes on goods with small income elasticities may be undesirable on equity grounds, which we have ignored by focusing on a single-consumer economy. Even from an efficiency perspective, if leisure and goods are not separable, then the effect of a dirty-good tax on labor supply will involve more direct substitution or complementarity considerations, which could be important. We are aware of little empirical work on substitution between labor supply and externality-related goods, but at least some work rejects separability between goods and leisure at a more general level (Browning and Meghir (1991)). This suggests that our understanding of environmentally motivated taxes can be strengthened significantly by further empirical study of the relationship between the supply of labor and the demand for externality-related goods.

References

Ballard, Charles L., and Steven G. Medema. (1993). "The Marginal Efficiency Effects of Taxes and Subsidies in the Presence of Externalities." *Journal of Public Economics* 52, 199-216.

Blundell, Richard, and Thomas MaCurdy. (1999). "Labor Supply: A Review of Alternative Approaches." In Orley Ashenfelter and David Card (eds.), *Handbook of Labor Economics, vol. 3A*. Amsterdam: Elsevier.

Bovenberg, A. Lans. (1999). "Green Tax Reforms and the Double Dividend - An Updated Reader's Guide." *International Tax and Public Finance* 6, 421-443.

Bovenberg, A. Lans, and Ruud de Mooij. (1994). "Environmental Levies and Distortionary Taxation." *American Economic Review* 84, 1085-1089.

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* 50, 59-88.

Bovenberg, A. Lans, and Lawrence H. Goulder. (2002). "Environmental Taxation and Regulation." In Alan Auerbach and Martin Feldstein (eds.), *Handbook of Public Economics, vol. 3*. Amsterdam: Elsevier.

Bovenberg, A. Lans, and F. van der Ploeg. (1994). "Environmental Policy, Public Finance, and the Labor Market in a Second-Best World." *Journal of Public Economics* 55, 349-390.

Browning, Martin, and Costas Meghir. (1991). "The Effects of Male and Female Labor Supply on Commodity Demands." *Econometrica* 59, 925-951.

Corlett, W.J., and D.C. Hague. (1953). "Complementarity and the Excess Burden of Taxation." *Review of Economic Studies* 21, 21-30.

Deaton, Angus. (1981). "Optimal Taxes and the Structure of Preferences." *Econometrica* 49, 1245-1260.

Federation of Tax Administrators. (2004). "State Excise Taxes." http://www.taxadmin.org/fta/rate/tax_stru.html.

Fullerton, Don. (1981). "Environmental Levies and Distortionary Taxation: Comment." *American Economic Review* 87, 245-251.

Fullerton, Don, and Gilbert E. Metcalf. (1998). "Environmental Taxes and the Double-Dividend Hypothesis: Did You Really Expect Something for Nothing?" *Chicago-Kent Law Review* 73, 221-256.

Goulder, Lawrence H., and Robertson C. Williams III. (2003). "The Substantial Bias from Ignoring General Equilibrium Effects in Estimating Excess Burden, and a Practical Solution." *Journal of Political Economy* 111, 898-927.

Gruber, Jonathan. (2001). "Tobacco at the Crossroads." *Journal of Economic Perspectives* 15, 193-212.

Gruber, Jonathan, and Botond Köszegi. (2002). "A Theory of Government Regulation of Addictive Bads: Optimal Tax Levels and Tax Incidence for Cigarette Excise Taxation." Working Paper 8777, National Bureau of Economic Research.

Heckman, James J. (1993). "What Has Been Learned About Labor Supply in the Past Twenty Years?" *American Economic Review* 83, 116-121.

Killingsworth, Mark. (1983). *Labor Supply*. Cambridge University Press, New York.

Kim, Sang-Kyum. (2000). "The Effect of Homotheticity on the Double Dividend and the Optimal Environmental Tax Rate." Ph.D. dissertation, Michigan State University (2000).

Oates, Wallace E. (1993). "Pollution Charges as a Source of Public Revenue." In H. Giersch (ed.), *Economic Progress and Environmental Concerns*. Berlin: Springer-Verlag.

Parry, Ian W.H. (1995). "Pollution Taxes and Revenue Recycling." *Journal of Environmental Economics and Management* 29, S64-S77.

Parry, Ian W.H. (1999). "The Double Dividend: When You Get It and When You Don't." "Proceedings of the 91st Annual Conference on Taxation", National Tax Association, Washington, D.C. (1999).

Parry, Ian W.H. (2003). "On the Costs of Excise Taxes and Income Taxes in the UK." *International Tax and Public Finance* 10, 281-304.

Parry, Ian W.H., and Antonio M. Bento. (2000). "Tax Deductions, Environmental Policy, and the 'Double Dividend' Hypothesis." *Journal of Environmental Economics and Management* 39, 67-96.

Parry, Ian W.H., and Kenneth A. Small. (2002). "Does Britain or the United States Have the Right Gasoline Tax?" Discussion Paper No. 02-12, Resources for the Future.

Pearce, David. (1991). "The Role of Carbon Taxes in Adjusting to Global Warming." *Economic Journal* 101, 938-948.

Sandmo, Agnar. (1976). "Optimal Taxation: An Introduction to the Literature." *Journal of Public Economics* 6, 37-54.

Schöb, Ronnie. (1997). "Environmental Taxes and Pre-existing Distortions: The Normalization Trap." *International Tax and Public Finance* 4, 167-176.

Schwartz, J., and Robert Repetto. (1997). "Nonseparable Utility and the Double Dividend Debate." Working Paper, World Resources Institute.

Stone, Richard. (1954). "Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand." *Economic Journal* 64, 511-527.

Tax Foundation. (2004). "Federal Excise Tax Rates, Selected Years 1944-2002." http://www.taxfoundation.org/exciseratesfed.html.

Terkla, David. (1984). "The Efficiency Value of Effluent Tax Revenues." *Journal of Environmental Economics and Management* 11, 107-123.

Williams III, Robertson C. (1999). "The Double Dividend When Environmental Quality Affects Health or Productivity." *Proceedings of the 91st Annual Conference on Taxation*. Washington, D.C.: National Tax Association.

Figure 1: The Ratio of the Optimal Tax on Gasoline to the Pigouvian Tax, for Various Values of the Gasoline Expenditure Elasticity and the Labor-Supply Elasticity (π = 1.0, Gasoline Expenditure Share = 0.02)

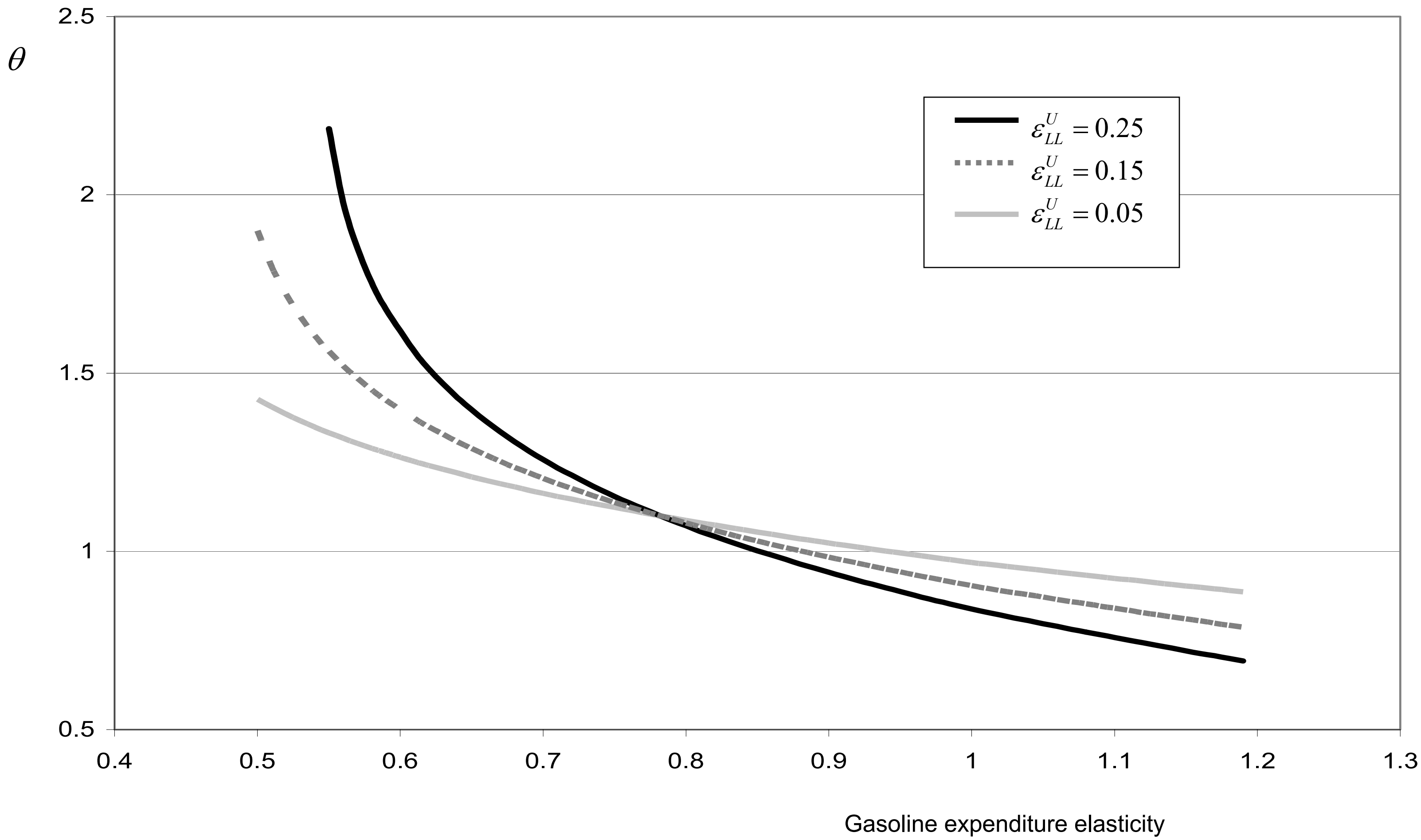
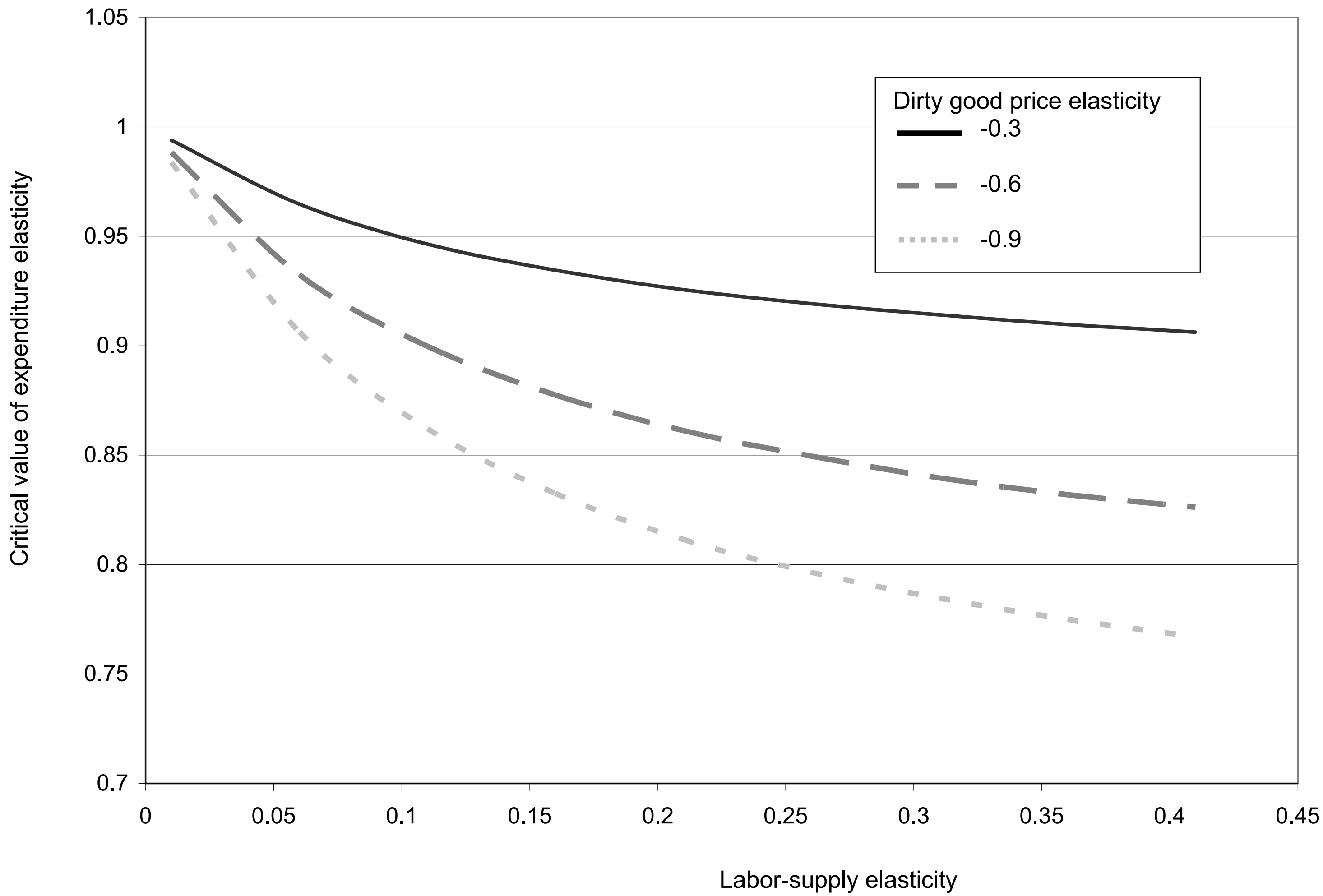


Figure 2: Critical Values of the Dirty Good Expenditure Elasticity, below which $\theta > 1$, For Various Values of the Dirty Good Price Elasticity and the Labor-Supply Elasticity ($\pi = 1.0$, Gasoline Expenditure Share = 0.02)



Appendix

Derivation of equation (8): Differentiating equation (7) with respect to t_D, using Roy's Identity, we have

$$\frac{d\tilde{W}}{dt_D} = -H_C\left(D + L\frac{dt_L}{dt_D}\right) - \pi\frac{dD}{dt_D}. \tag{A1}$$

From the revenue-neutrality requirement,

$$t_D\frac{dD}{dt_D} + t_L\frac{dL}{dt_D} = -(D + L\frac{dt_L}{dt_D}). \tag{A2}$$

Substitution of (A2) into (A1) leads to Equation (8).

Measurement of Welfare Change: See Kim [17] for more details on the derivation of equations (11)-(13). Differentiating (11) with respect to Z:

$$W_Z \equiv \frac{\partial W}{\partial Z} = \frac{1}{P^*} - \pi\frac{\partial D}{\partial Z}. \tag{A3}$$

$\partial D/\partial Z$ is a constant, given prices, and therefore so is W_Z. Also, $\tilde{W}_Z(t_D) = W_Z((1+t_D),(1-t_L(t_D)))$. The equivalent variation for a revenue-neutral change from $t_D = 0$ to some $t'_D > 0$ is thus

$$EV(t'_D, t_D = 0) = \frac{\left[\tilde{W}(t'_D) - \tilde{W}(t_D = 0)\right]}{\tilde{W}_Z(t_D = 0)}. \tag{A4}$$

$\underline{dL/dt_D}$: Without imposing separability or homotheticity on $H(\cdot)$, we may write

$$\frac{dL}{dt_D} = \frac{\partial L}{\partial w}\left(-\frac{dt_L}{dt_D}\right) + \frac{\partial L}{\partial t_D}, \tag{A5}$$

where $w \equiv (1 - t_L)$.

Using the revenue-neutrality condition (A2),

$$\frac{dL}{dt_D} = \frac{\partial L}{\partial w}\left(\frac{1}{L}\right)\left(t_D \frac{dD}{dt_D} + D + t_L \frac{dL}{dt_D}\right) + \frac{\partial L}{\partial t_D}, \tag{A6}$$

which implies

$$\frac{dL}{dt_D} = \left(\frac{1}{1 - \varepsilon_{LL}^U \left(t_L/w\right)}\right)\left(\left(\varepsilon_{LL}^U/w\right) t_D \frac{dD}{dt_D} + \frac{\partial L}{\partial w}\frac{D}{L} + \frac{\partial L}{\partial t_D}\right). \tag{A7}$$

Decomposing the uncompensated derivatives and making use of Slutsky symmetry of cross-price effects, it can be shown that

$$\frac{\partial L}{\partial w}\frac{D}{L} + \frac{\partial L}{\partial t_D} = \left.\frac{\partial L}{\partial w}\right|_{\bar{U}} \frac{D}{L} - \left.\frac{\partial D}{\partial w}\right|_{\bar{U}}. \tag{A8}$$

Imposing weak separability between goods and leisure implies that the effect of a change in w on D works entirely through the change in expenditure:

$$\left.\frac{\partial D}{\partial w}\right|_{\bar{U}} = \left.\frac{\partial I}{\partial w}\right|_{\bar{U}} \cdot \frac{\partial D}{\partial I}, \tag{A9}$$

where I denotes expenditure. In addition,

$$\left.\frac{\partial I}{\partial w}\right|_{\bar{U}} \equiv \left.\frac{\partial (wL)}{\partial w}\right|_{\bar{U}} = \left.\frac{\partial L}{\partial w}\right|_{\bar{U}} \cdot w. \tag{A10}$$

Then letting ee_D denote the expenditure elasticity of demand for the dirty good, (A8)-(A10) may be used to rewrite (A7) as

$$\frac{dL}{dt_D} = \left(\frac{1}{w - \varepsilon_{LL}^U t_L}\right)\left(\varepsilon_{LL}^U \cdot t_D \frac{dD}{dt_D} + \varepsilon_{LL}^C \cdot D\left(1 - ee_D\right)\right), \tag{A11}$$

where ε_{LL}^C is the compensated wage elasticity of labor supply.

In the homothetic case, $ee_D = 1$. Therefore, dL/dt_D vanishes at $t_D = 0$, and for positive t_D takes the opposite sign of the uncompensated wage elasticity (because $dD/dt_D < 0$, and assuming $w - \varepsilon_{LL}^U t_L > 0$). Without homotheticity, but maintaining separability between goods and leisure, dL/dt_D is positive at $t_D = 0$ (and so therefore is the second dividend) whenever $ee_D < 1$.

Endnotes

* The authors are grateful to Don Fullerton, Larry Goulder, Larry Martin, Gib Metcalf, Ian Parry, Michael Smart, Rob Williams, and anonymous referees for helpful comments. Any errors are our responsibility.

[1] In this paper, we use the phrase "environmental tax" to refer to a large number of situations in which a tax could be used to correct for an externality. Our analytical framework could be applied to a large number of specific externalities, including air and water pollution, solid waste, etc. In particular, we apply our framework to the case of gasoline taxes, which have been discussed in terms of their effects on several environmental externalities. These include local air pollution, global pollution leading to global warming, and traffic congestion. We also apply our framework to cigarette taxes, which have also been discussed in terms of their effects on an environmental externality in the form of second-hand smoke. Of course, cigarette taxes have also been justified as taxes on "sin". Thus, externality correction is not the sole justification for those taxes. Also, we do not claim that our analysis of non-homothetic preferences is relevant for *every* environmental issue. Nevertheless, we believe it is appropriate to couch our discussion in terms of environmental taxes.

[2] This literature has grown tremendously in recent years. Surveys can be found in Fullerton and Metcalf (1998), Bovenberg (1999), and Parry (1999).

[3] These conditions on preferences are well known to be sufficient for the optimality of uniform taxation, in the absence of environmental concerns: See Sandmo ((1976), p. 45).)

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[4] Unless there are difficulties of administration or detection, an emissions tax is likely to be superior to a tax on dirty outputs. See Ballard and Medema (1993).

[5] Fullerton (1997) points out that the precise interpretation of the results of B-de M depends on the way in which the initial tax system is normalized. (Also see Schöb (1997).)

[6] Using Z gives us a simple way of showing certain income derivatives. However, Z is held constant at zero in our simulation experiments.

[7] See also equation (16) in Bovenberg and van der Ploeg (1994). Bovenberg and Goulder (2002) define t_L as a tax on the net wage, whereas our t_L amounts to a tax on the gross wage. Thus their t_L translates to our $t_L/(1-t_L)$.

[8] A recent paper by Goulder and Williams (2003) finds that effects on labor supply typically lead to a substantial *increase* in the excess burden of an excise tax, when compared with estimates based on simpler formulas that ignore such effects. For example, in their general-equilibrium model, which includes a 40-percent labor tax, a 65-percent excise tax on cigarettes creates an excess burden that is 1.2 to 2.6 times as large as would be calculated from a simple Harberger triangle, depending on the assumed price elasticity of demand for cigarettes. These results may seem to imply that optimal externality-correcting tax rates are much lower than Pigouvian rates. However, this is not the case. The most important reason that their results differ from ours is that, in focusing on excess burden, they rule out the revenue-recycling effect. In the model of Goulder and Williams, the excise-tax revenue is returned to the consumer in a lump-sum fashion, rather than being used to reduce the labor tax. They also assume that the goods utility

function is homothetic in their illustrative calculations, and this also explains part of the difference.

[9] The generalized CES function is closely related to the well-known linear expenditure system (LES). (See Stone (1954).) In the LES, the elasticity of substitution between the discretionary consumptions of the various goods is constrained to be unitary. (For parameter combinations that imply a unitary elasticity of substitution, we use the LES rather the generalized CES.) In the generalized CES, the elasticity of substitution may take on any value. This gives us an additional degree of freedom in the calibration process.

[10] This result is closely related to the point made by Parry (1995).

[11] Our simulations are focused primarily on the markets for gasoline and tobacco. In the U.S. and many other countries, these commodities are already taxed at substantial rates. Studies of price and expenditure elasticities have been conducted in the presence of these taxes. We therefore calibrate our model assuming a base value of $t_D = 0.5$.

[12] This result is roughly consistent with Parry and Small (2002), who find that the optimal tax is about $1 per gallon, compared to their estimate of 74 cents per gallon for the Pigouvian tax rate. The Federal excise tax is 18.4 cents per gallon, and Rhode Island is the only state with a gasoline tax in excess of 30 cents per gallon. (For Federal excise tax rates, see Tax Foundation (2004). For excise tax rates for the 50 states, see Federation of Tax Administrators (2004).) This suggests that gasoline taxes in the United States are well below their optimal levels. (Note, however, that the actual tax rates in the United Kingdom are much higher than those in the U.S., and are thus probably greater than the optimal rates. See Parry (2003).)

[13] Expenditure elasticities greater than one involve $D^* = 0$ and $C^* > 0$.

[14] The Federal excise tax on cigarettes is 39 cents per pack. The state taxes vary widely. As of January 1, 2004, state taxes ranged from a high of $2.05 per pack in New Jersey to a low of 2.5 cents per pack in Virginia. Based on our reading of the evidence on the value of π, we conclude that the tax on cigarettes is almost certainly below its optimal level in the states with the lowest tax rates. However, if one accepts the rational-addiction model, the tax on cigarettes may be above its optimal level in the states with the highest tax rates.

[15] While the choice of functional form may make little difference for small policy changes, different functional forms might imply rather different behavior far from the base equilibrium. A related problem occurs in models that derive analytical expressions for θ. By their nature, analytical models based on differential calculus are not well suited for analysis of large policy changes. Thus, such models ignore the problem mentioned here.