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**First, Do No Harm:
Welfare Gains and Welfare Losses from Environmental Taxation**

Charles L. Ballard*
Michigan State University

John H. Goddeeris*
Michigan State University

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* Department of Economics, Michigan State University, East Lansing, MI 48824-1038.
Ballard: (517) 353-2961; ballard@msu.edu. Goddeeris: (517) 353-6466;
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ABSTRACT

We clarify the relationship between the “double dividend” (associated with a marginal change from the existing tax system) 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. We also show that, if environmental taxes are increased beyond their second-best optimal level, there is a rapid increase in the non-environmental costs of tax distortions. Our calculations suggest that, for typical parameter combinations, there will be overall welfare *losses* when the tax rate is increased to somewhat more than twice the optimal level.

Keywords: Environmental taxation; General-equilibrium efficiency analysis

JEL Classification: H21; H23; D58

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“Make a habit of two things—to help, or at least to do no harm.”
-- Hippocrates, *Epidemics*, Book 1, Section XI

I. 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.¹ If this situation exists, then policymakers would be encouraged to err on the high side when choosing the size of environmental taxes.

These two situations are related, but not identical. The first is concerned with incremental tax reform, around a tax system with no environmentally motivated taxes. If a marginal change from the existing tax system generates a welfare improvement (even when the environmental benefits are ignored), then we have a double dividend. The

¹ Pigou (1947) developed the intuition for the case in which the government can raise all of its revenue through some combination of externality-correcting taxes and lump-sum taxes. In this simple (but unrealistic) case, the optimal tax on pollution is exactly equal to the marginal environmental damage.

second situation is concerned with marginal changes in the neighborhood of the first-best Pigouvian tax rate.

A rapidly growing literature is concerned with the conditions under which one or the other of these two happy situations can occur. However, relatively less attention has been devoted to a potential outcome that is decidedly less felicitous. If an environmental tax is pushed beyond its optimal level, the marginal distortion caused by the tax is greater than the marginal improvement caused by the reduction in the environmental externality. Under standard assumptions, the marginal distortions caused by each successive increment to the environmental tax will be increasing. Thus, as we increase the environmental tax farther and farther beyond its optimal level, overall welfare will continue to fall. If the tax is increased far enough, welfare will actually decrease to a level below that which would have occurred if no environmental tax had ever been imposed.

In this paper, we employ a small-scale computational general equilibrium model, with which we study (a) the double dividend, (b) the relationship between the second-best optimal environmental tax rate and the first-best Pigouvian tax rate, and (c) the situation under which the environmental tax is so high that the welfare gain is driven to zero.

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), were considerably less optimistic. These papers cast serious doubt on whether a revenue-

neutral substitution of an environmental tax for another tax (such as a tax on labor income) 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)), “...environmental taxes typically exacerbate, rather than alleviate, preexisting tax distortions-- even if revenues are employed to cut preexisting distortionary taxes... [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).

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

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 changed so that environmental taxes may have non-environmental benefits. If it is assumed that environmental quality is not separable from leisure in the utility function, so that 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 analyze the relationship between the structure of preferences and the non-environmental effects of environmentally motivated taxes. However, we focus on an aspect of preferences that is different from the one emphasized by Schwartz and Repetto and by Williams. We consider the possibility of non-homothetic preferences among goods.

Even though we will ultimately study non-homothetic preference structures, we begin with a simulation model that fits B-de M's assumptions, which include separability between goods and leisure, as well as homotheticity. (Thus, the B-de M model satisfies the conditions that are sufficient for the optimality of uniform taxation, in the absence of environmental concerns: See Sandmo (1976, p. 45).)

Using our numerical specification of the B-de M model, we verify numerically their analytic results: 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. However, this does not mean that environmental taxation cannot be beneficial when the assumptions of Bovenberg and de Mooij are used. It only means that the environmental tax has only environmental benefits (i.e., the benefits of cleaning up the environment are the only dividend from the environmental tax).

In our representation of the model of B-de M, the second-best optimal tax rate is positive, even though the environmental tax does not bring about any non-environmental benefits. Over a fairly wide range of environmental tax rates, the environmental benefits outweigh the non-environmental distortions. However, if the environmental tax is raised sufficiently far, the non-environmental distortions will eventually overwhelm the environmental benefits. Over a wide range of parameter combinations, we find that the net benefit goes to zero when the environmental tax is between 2 and 2.5 times as great as the second-best optimal tax rate. This is a sobering result. This entire literature arose because of the substantial uncertainty regarding the magnitude of the environmental benefits of environmental taxes. We find that there is some margin for error: If we were to miss the optimal tax rate by 50% in either direction, we would still have positive net benefits. However, if we were to use a tax rate even 2.5 times as great as the optimal tax rate, the net benefits would be less than zero. This should give further urgency to the need to refine our estimates of the environmental benefits.

After we analyze the model using the assumptions of B-de M, we then use a non-homothetic model to show that environmental taxes can generate non-environmental benefits, over a wide range of parameter values. We also shed light on the relationship between the double dividend and the situation in which the optimal environmental tax is

greater than the Pigouvian tax. We find that the parameter combinations that can lead to these two situations are actually quite similar. When we introduce non-homotheticity, our results for the relationship between the optimal tax rate and the rate at which the net benefits are driven to zero are very similar to the results from the homothetic case. In most cases, the net benefits go to zero when the environmental tax rate is somewhat more than twice as large as the optimal tax rate.

Much of this literature concentrates on taxes on “dirty goods” (*i.e.*, goods for which the production process creates a negative externality). In keeping with that literature, our simulations will also concentrate on dirty-goods taxes. However, similar results occur in a similar model in which emissions are taxed directly. (See Kim (2000).)³

II. 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:

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

³ 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).

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

$$L = C + D + G . \quad (2)$$

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

$$U = H(C, D, V) - p D + G , \quad (1')$$

where p is the marginal damage parameter. Since we consider experiments in which public expenditure is 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 (t_D) and taxes on labor (t_L).⁴ 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

⁴ 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).)

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.⁵ The budget constraint is

$$(1-t_L)L + Z = (1+t_D)D + C . \quad (3)$$

The government's budget constraint is

$$t_L L + t_D D = G . \quad (4)$$

Household maximization of $H(\cdot)$ subject to (3) leads to an indirect utility function $W((1+t_D), (1-t_L), Z, p, G)$. Although $W(\cdot)$ incorporates the externality and the public good, those effects are assumed to be exogenous to the household.

We may now consider the optimal choice of t_D and t_L , maximizing $W(\cdot)$ subject to (4), with p and G fixed and $Z = 0$. If lump-sum taxes were available, they would be used to meet revenue needs, and the optimal Pigouvian tax on the dirty good would be

$t_D^{pig} = p / H_C$, 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). We call this the first-best optimal Pigouvian tax.

⁵ Using Z gives us a simple way of showing certain income derivatives. However, the income derivatives are only necessary in a part of the analysis that follows. Thus, Z will be set to zero in much of the following.

However, lump-sum taxes are not generally available. Bovenberg and Goulder show that, without lump-sum taxes, the following holds at the optimal t_D and t_L :

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

where e_{ik} is the compensated demand elasticity for commodity i with respect to the price of commodity k , and $h = m/H_C$, where μ is the Lagrange multiplier for the government budget constraint (i.e., the utility cost of raising a dollar of government revenue).⁶

Equation (5) shows that the optimal tax on the dirty good can be separated into a “Ramsey” component derived from 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 $e_{CL} > e_{DL}$. An analogous condition was first discussed by Corlett and Hague (1953), and it implies a differential tax on the good that is most complementary to leisure.

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. We will maintain the separability assumption, but allow for non-

⁶ See equation (16) in Bovenberg and van der Ploeg (1994). Bovenberg and Goulder define t_L as a tax on the net wage, whereas ours amounts to a tax on the gross wage. Thus their t_L translates to our $t_L/(1-t_L)$.

homotheticity. In the B-de M case, $e_{CL} = e_{DL}$, so the Ramsey term vanishes. It follows that the optimal t_D is the Pigouvian rate divided by h , which here specializes to

$$h = \left(1 - \frac{t_L}{(1-t_L)} e_{LL}^U \right)^{-1}, \quad (6)$$

where e_{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 $e_{LL}^U > 0$.

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. This balances the beneficial effect on 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 $\tilde{W}(t_D; p, G)$ as

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

we show in the Appendix that

$$\frac{d\tilde{W}/dt_D}{W_Z} = -\frac{p}{W_Z} \frac{dD}{dt_D} + \left(t_D \frac{dD}{dt_D} + t_L \frac{dL}{dt_D} \right), \quad (8)$$

where W_Z is the private marginal utility of income, which also equals H_C , the marginal utility of the untaxed numeraire.

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 $t_L dL/dt_D$, so that $d\tilde{W}/dt_D$ 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 the expenditure elasticity of demand for D .

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 to leisure than 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)).

III. 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 :

$$H = \left[b^{\frac{1}{s}} V^{\frac{s-1}{s}} + (1-b)^{\frac{1}{s}} Q^{\frac{s-1}{s}} \right]^{\frac{s}{s-1}}, \quad (9)$$

where s is the elasticity of substitution between leisure and the composite good. The “weighting parameter,” b , is used in calibrating the model to particular elasticity values.

We introduce non-homotheticity in a simple way. The subutility function for goods is of the “generalized CES” form. This is a CES function in which utility is only generated when consumption is greater than some pre-specified level, which can be interpreted as a “minimum consumption requirement.”⁷ C^* and D^* are the “requirements” for the clean good and the dirty good. The subutility function is

⁷ The generalized CES function is closely related to the well-known linear expenditure system. (See Stone (1954).) In the linear expenditure system, the elasticity of substitution between the discretionary consumptions of the various goods is constrained to be unitary. 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.

$$Q = \left[a^{\frac{1}{n}} (D - D^*)^{\frac{n-1}{n}} + (1-a)^{\frac{1}{n}} (C - C^*)^{\frac{n-1}{n}} \right]^{\frac{n}{n-1}}, \quad (10)$$

where v 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^*) .⁸

Indirect utility is

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

where $P^* = [b(1-t_L)^{(1-s)} + (1-b)P_Q^{(1-s)}]^{\frac{1}{1-s}}$ is the ideal price index for the outer nest of the utility function, and $P_Q = [a(1+t_D)^{(1-n)} + (1-a)]^{\frac{1}{1-n}}$ is the ideal price index for goods. The demand function for the dirty good and the labor-supply function are

$$D((1+t_D), (1-t_L), Z) = \frac{a((1-t_L)L - (1+t_D)D^* - C^* + Z)}{(1+t_D)^n P_Q^{(1-n)}} + D^* \quad (12)$$

$$L((1+t_D), (1-t_L), Z) = 1 - \frac{b((1-t_L) - (1+t_D)D^* - C^* + Z)}{(1-t_L)^s P^{*(1-s)}}. \quad (13)$$

⁸ Setting $C^* = D^* = 0$ gives an ordinary CES, which is homothetic, consistent with the B-de M model.

Equation (11) says that 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.

With $D^* > 0$ and $C^* = 0$, the expenditure elasticity of demand for the dirty good is less than one. Thus, the dirty good is relatively complementary with leisure. In this situation, equation (8) remains valid as an expression for the effect of an increase in t_D on welfare. However, as shown in the Appendix, the expression for dL/dt_D now includes an additional term that is definitely positive at $t_D = 0$, regardless of the sign of the uncompensated labor-supply elasticity. It follows 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.⁹ Viewed another way, the tax on the dirty good is now relatively less distorting because part of it falls on D^* . Therefore, in this model with minimum required consumption, it is as if a portion of the tax on D is a lump-sum tax. Equation (8) and equation (A10) in the Appendix together imply that, for given values of p and the price elasticity of demand for the dirty good, the second dividend at $t_D = 0$ will increase with the compensated wage elasticity of labor supply, and decrease with the expenditure elasticity of demand for the dirty good.

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

In our simulations, we consider cases where $D^* > 0$ and $C^* = 0$. We use D^* to calibrate to the desired value of the expenditure elasticity of demand for the dirty good.

⁹ This result is closely related to the point made by Parry (1995).

We also calibrate the model to a set of values for the labor-supply elasticities. Based on the discussions in Killingsworth (1983), Heckman (1993), and Blundell and MaCurdy (1999), we choose 0.25 for our central-case value of the uncompensated labor-supply elasticity, and -0.15 for the total-income elasticity of labor supply.

In the base case, a labor-income tax of 40 percent is the only tax in this economy. In the revised case, a portion of the labor tax is replaced with the new 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.

We define $j = (D^*/D)$ in the base case. Figure 1 illustrates the welfare trajectories for $p = 0.1$ and j values of 0.1, 0.2, and 0.3. In all of these cases, the marginal damage at the second-best optimum is about 0.098. Increasing j reduces the expenditure elasticity of dirty-good demand, and therefore increases the non-environmental benefits of the tax. As expected, when we increase j while holding other things constant, we see an increase in the ratio of optimal tax to marginal damage. As Figure 1 shows, an increase in j also increases the net welfare gains from the environmental tax. In all cases, however, the net welfare gains eventually become negative if the tax is set too high.

Table 1 shows some more details for the simulations depicted in Figure 1, and it also reports information for some additional simulations, for different values of p . Table 1 shows some fairly consistent patterns. In these cases, with $j > 0$ and $C^* = 0$, the optimal Pigouvian tax is always greater than the first-best Pigouvian tax. The difference between the optimal Pigouvian tax and the first-best tax increases as j increases. (In

other words, as the expenditure elasticity of demand for the dirty good decreases, it becomes more and more attractive to tax the dirty good.) Another important consistency in Table 1 is in the ratio of the tax rate at which net welfare gains fall to zero, and the optimal tax rate. In the vast majority of cases, this ratio is between 2 and 2.5. The ratio tends to grow as p increases, although the basic character of the results is unchanged over a fairly broad range of values for p . Also, not surprisingly, the ratio tends to be larger when j is larger.

We have only reported cases for which $D^* > 0$ and $C^* = 0$. In the opposite case, with $C^* > 0$ and $D^* = 0$, the dirty good will have expenditure elasticity of demand greater than unity, and will be the more substitutable with leisure. In that case, the second dividend will be negative at $t_D = 0$ and the B-de M results will be reinforced. More generally, a positive second dividend will exist at $t_D = 0$ if and only if $D^*/D > C^*/C$. Additional results of sensitivity analyses for variations in parameter values are available upon request.

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. We have seen that, in this model, there is a double dividend whenever D^*/D is even infinitesimally greater than C^*/C . However, we have performed simulations over a very wide range of parameter combinations, and in the vast majority of cases, if there is a double dividend, it is also true that the optimal environmental tax rate is greater than the Pigouvian tax rate. Thus,

even though the two concepts are theoretically distinct, they are generated by rather similar combinations of parameters. For additional discussion, see Kim (2000).

Some additional *caveats* are in order, however. 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)). A double dividend at $t_D = 0$ also does not imply that the optimal tax is larger than Pigouvian, although in most cases we have considered the two phenomena occurred together.

V. Conclusion

A number of studies have suggested that environmental taxes can only generate positive non-environmental effects in unusual circumstances. However, in virtually all cases, these papers assume that the utility function among goods is homothetic and separable from the utility derived from leisure. In the simplest model, in which (1) labor services are 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, the assumptions of homotheticity and separability are sufficient to guarantee that there is no double dividend. Also, in this case, the optimal environmental tax rate will be below the Pigouvian tax rate, unless the labor-supply elasticity is negative.

In this paper, 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. 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. And, in fact, many of the goods that are thought to involve external costs do have expenditure elasticities that are less than one. For some specific applications to tobacco and gasoline, see Ballard, Goddeeris, and Kim (2004). In many such cases, the optimal tax rate on the dirty good can be substantially larger than the marginal environmental damage.

Thus, in one sense, our results are more optimistic than much of the recent literature, regarding the welfare effects of environmental taxes. However, it is important not to claim too much. As illustrated in Table 1 and Figure 1, if the environmental tax rate is increased too far, it can actually lead to overall welfare losses, despite the cleaner environment. Our calculations usually suggest that this unfortunate effect occurs when the environmental tax rate is somewhat more than twice as great as the first-best Pigouvian rate. This entire literature is largely motivated by the substantial uncertainty about the size of the marginal environmental damages. Of course, if we are uncertain about the size of the marginal environmental damages, then we are also uncertain about the level of the Pigouvian tax rate. Consequently, if our guesses about the size of the marginal environmental damages are inaccurate, it is entirely possible that well-meaning

tax reforms could actually make society worse off. It remains urgently necessary to refine our estimates of the environmental costs of environmental pollution.

In this paper, we have presented calculations over a range of values for j (which controls the expenditure elasticity of demand for the dirty good) and p (the parameter representing the size of the marginal environmental damage). While this represents a good start, there is much to be done. In the near future, we plan to perform additional simulations, over an even wider range of values for j and p . We also will conduct sensitivity analyses with respect to the compensated and uncompensated labor-supply elasticities, and the expenditure share for the dirty good.

REFERENCES

- Ballard, C.L., J.H. Goddeeris, and S.K. Kim (2004). Non-Homothetic Preferences and the Non-Environmental Effects of Environmental Taxes. *International Tax and Public Finance*, forthcoming.
- Ballard, C.L., and S.G. Medema (1993). The marginal efficiency effects of taxes and subsidies in the presence of externalities, *Journal of Public Economics* **52**, 199-216.
- Blundell, R., and T. MaCurdy (1999). Labor supply: a review of alternative approaches, in “Handbook of Labor Economics, vol. 3A” (O. Ashenfelter and D. Card, eds.), Amsterdam: Elsevier.
- Bovenberg, A.L. (1999). Green tax reforms and the double dividend - An updated reader’s Guide, *International Tax and Public Finance* **6**, 421-443.
- Bovenberg, A.L., and R. de Mooij (1994). Environmental levies and distortionary taxation, *American Economic Review* **84**, 1085-1089.
- Bovenberg, A.L., and L.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.L., 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, M. and C. 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, A. (1981). Optimal taxes and the structure of preferences, *Econometrica* **49**, 1245-1260.
- Fullerton, D. (1997). Environmental levies and distortionary taxation: Comment, *American Economic Review* **87**, 245-251.
- Fullerton, D., and G.E. Metcalf (1998). Environmental taxes and the double-dividend hypothesis: Did you really expect something for nothing?, *Chicago-Kent Law Review* **73**, 221-256.
- Gruber, J. (2001). Tobacco at the crossroads: The past and future of smoking regulation in the United States, *Journal of Economic Perspectives* **15**, 193-212.
- Gruber, J., and B. Koszegi (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, J.J. (1993). What has been learned about labor supply in the past twenty years?, *American Economic Review* **83**, 116-121.
- Killingsworth, M. (1983). "Labor Supply", Cambridge University Press, New York.
- Kim, S.K. (2000). The effect of homotheticity on the double dividend and the optimal environmental tax rate, Ph.D. dissertation, Michigan State University.
- Oates, W.E. (1993). Pollution charges as a source of public revenue, in "Economic Progress and Environmental Concerns" (H. Giersch, Ed.), Springer-Verlag, Berlin.
- Parry, I.W.H. (1995). Pollution taxes and revenue recycling, *Journal of Environmental Economics and Management* **29**, S64-S77.

- Parry, I.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.
- Parry, I.W.H., and A.M. Bento (2000). Tax deductions, environmental policy, and the 'double dividend' hypothesis, *Journal of Environmental Economics and Management* **39**, 67-96.
- Parry, I.W.H., and K.A. Small (2002). Does Britain or the United States have the right gasoline tax?, Discussion paper no. 02-12, Resources for the Future.
- Pearce, D. (1991). The role of carbon taxes in adjusting to global warming, *Economic Journal* **101**, 938-948.
- Pigou, A.C. (1947). "A study in public finance", Macmillan, London.
- Sandmo, A. (1976). Optimal taxation: An introduction to the literature, *Journal of Public Economics* **6**, 37-54.
- Schöb, R. (1997). Environmental taxes and pre-existing distortions: The normalization trap, *International Tax and Public Finance* **4**, 167-176.
- Schwartz, J., and R. Repetto (1997). Nonseparable utility and the double dividend debate, Working Paper, World Resources Institute.
- Stone, R. (1954). Linear expenditure systems and demand analysis: An application to the pattern of British demand, *Economic Journal* **64**, 511-527.
- Terkla, D. (1984). The efficiency value of effluent tax revenues, *Journal of Environmental Economics and Management* **11**, 107-123.

Williams, III, R.C. (1999). The double dividend when environmental quality affects health or productivity, "Proceedings of the 91st Annual Conference on Taxation", National Tax Association, Washington, D.C.

Figure 1: Environmental Taxes and Welfare Change, Varying Homotheticity
($p = 0.1$, Central-Case Parameter Values)

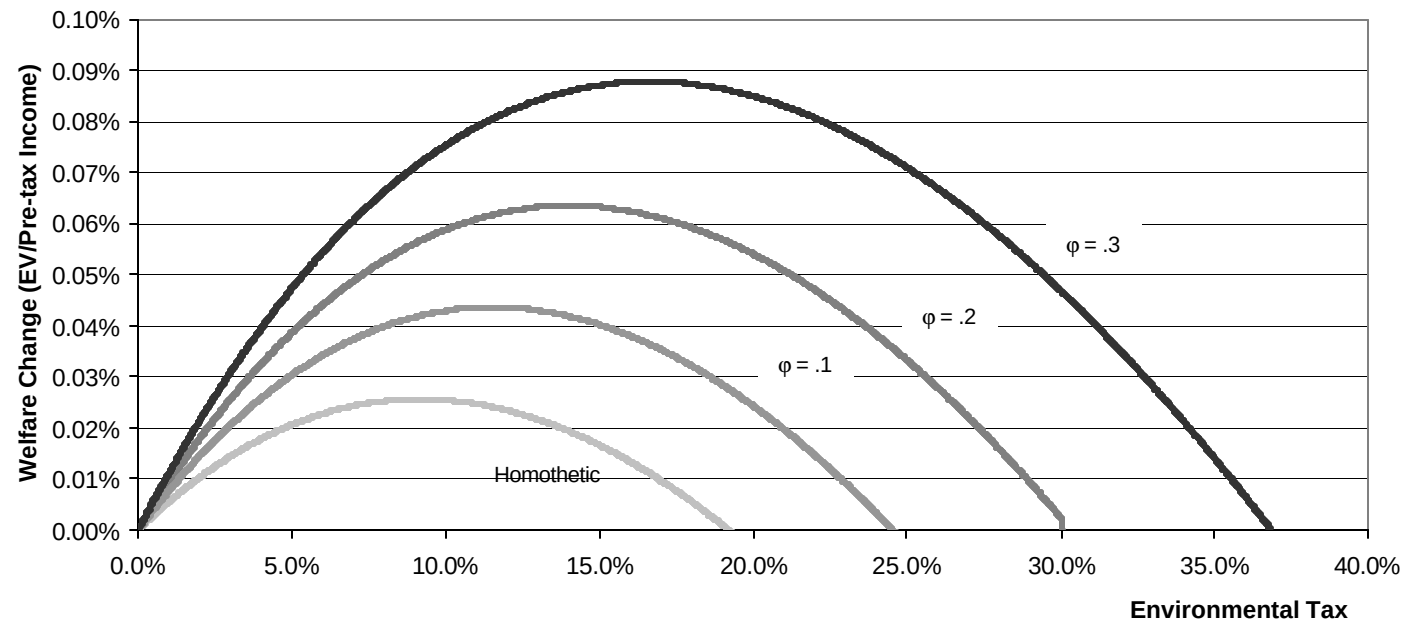


Table 1. Optimal Environmental Taxes For Various j Ratios, $C^* = 0$

	$j = 10\%$, expenditure elasticity = 0.92			$j = 20\%$, expenditure elasticity = 0.83			$j = 30\%$, expenditure elasticity = 0.75		
π	Marginal Damage	Optimal Tax	Maximum Tax, $EV > 0$	Marginal Damage	Optimal Tax	Maximum Tax, $EV > 0$	Marginal Damage	Optimal Tax	Maximum Tax, $EV > 0$
0.03	2.91%	4.93%	10.13%	2.92%	7.25%	15.11%	2.92%	9.68%	20.55%
0.05	4.86%	6.80%	14.10%	4.88%	9.16%	19.30%	4.89%	11.66%	25.03%
0.07	6.83%	8.67%	18.18%	6.85%	11.09%	23.61%	6.86%	13.63%	29.64%
0.10	9.80%	11.52%	24.51%	9.83%	14.00%	30.32%	9.84%	16.64%	36.84%
0.15	14.82%	16.33%	35.65%	14.85%	18.93%	42.15%	14.86%	21.71%	49.57%
0.20	19.92%	21.22%	47.56%	19.94%	23.94%	54.83%	19.94%	26.86%	63.30%
0.25	25.09%	26.22%	60.29%	25.10%	29.03%	68.41%	25.09%	32.10%	78.10%
0.30	30.34%	31.29%	73.87%	30.33%	34.21%	82.96%	30.29%	37.41%	94.02%

Appendix

Derivation of equation (8): For appropriately defined $V((1+t_D), (1-t_L), Z)$, equation (7) holds for utility functions of the form of (1'), as well as for more general $H(\cdot)$ functions. (Homotheticity and separability between goods and leisure are not required.) Equation (8) is also true under these more general conditions. Differentiating equation (7), and treating t_L as a function of t_D , we have

$$\frac{d\hat{V}}{dt_D} = \frac{\partial V}{\partial t_D} + \frac{\partial V}{\partial t_L} \frac{dt_L}{dt_D} - p \frac{dD}{dt_D}. \quad (\text{A1})$$

By Roy's Identity, $\frac{\partial V}{\partial t_D} = -DV_Z$ and $\frac{\partial V}{\partial t_L} = -LV_Z$. The latter equality reflects the fact that an increase in t_L reduces the price of leisure but also reduces the value of the time endowment. Thus,

$$\frac{d\hat{V}}{dt_D} = -V_Z \left(D + L \frac{dt_L}{dt_D} \right) - p \frac{dD}{dt_D}. \quad (\text{A2})$$

From the revenue-neutrality requirement,

$$t_D \frac{dD}{dt_D} + t_L \frac{dL}{dt_D} = -(D + L \frac{dt_L}{dt_D}). \quad (\text{A3})$$

Substitution of (A3) into (A2) leads to Equation (8).

dL/dt_D : Since the labor/leisure choice is already distorted by the labor tax, the effect on labor supply of a revenue-neutral increase in the dirty-good tax (dL/dt_D) is crucial for welfare. Without imposing separability or homotheticity, we may write

$$\frac{dL}{dt_D} = \frac{\partial L}{\partial w} \left(-\frac{dt_L}{dt_D} \right) + \frac{\partial L}{\partial t_D}, \quad (\text{A4})$$

where $w \equiv (1 - t_L)$. Using the revenue-neutrality condition (A3),

$$\frac{dL}{dt_D} = \frac{\partial L}{\partial w} \left(\frac{1}{L} \right) \left(t_D \frac{dD}{dt_D} + D + t_L \frac{dL}{dt_D} \right) + \frac{\partial L}{\partial t_D}, \quad (\text{A5})$$

which implies

$$\frac{dL}{dt_D} = \left(\frac{1}{1 - ue(t_L/w)} \right) \left((ue/w) t_D \frac{dD}{dt_D} + \frac{\partial L}{\partial w} \frac{D}{L} + \frac{\partial L}{\partial t_D} \right), \quad (\text{A6})$$

where ue denotes the uncompensated wage elasticity of labor supply.

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

$$\frac{\partial L}{\partial w} \frac{D}{L} + \frac{\partial L}{\partial t_D} = \frac{\partial L}{\partial w} \Big|_{\bar{U}} \frac{D}{L} - \frac{\partial D}{\partial w} \Big|_{\bar{U}}. \quad (\text{A7})$$

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:

$$\frac{\partial D}{\partial w} \Big|_{\bar{U}} = \frac{\partial I}{\partial w} \Big|_{\bar{U}} \cdot \frac{\partial D}{\partial I}, \quad (\text{A8})$$

where I denotes expenditure. In addition,

$$\frac{\partial I}{\partial w} \Big|_{\bar{U}} \equiv \frac{\partial(wL + Z)}{\partial w} \Big|_{\bar{U}} = \frac{\partial L}{\partial w} \Big|_{\bar{U}} \cdot w. \quad (\text{A9})$$

Then letting ce denote the compensated wage elasticity of labor supply, and ee_D denote the expenditure elasticity of dirty-good demand, we use (A7)-(A9) to rewrite (A6) as

$$\frac{dL}{dt_D} = \left(\frac{1}{1 - (1 + ue)t_L} \right) \left(ue \cdot t_D \frac{dD}{dt_D} + ce \cdot D (1 - ee_D) \right). \quad (\text{A10})$$

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 $1 - (1 + ue)t_L > 0$). 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 $ee_D < 1$, assuming $ce > 0$. When t_D is positive, the other term in (A10) also comes into play.