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Department of Economics
Tufts University
Medford, MA 02155
(617) 627 – 3560
http://ase.tufts.edu/econ

A Note on Weak Double Dividends[*]

Gilbert E. Metcalf[**]
Department of Economics
Tufts University
and
NBER

Mustafa H. Babiker
Arab Planning Institute
and
MIT Joint Program on the Science and Policy of Global Change

and

John Reilly
MIT Joint Program on the Science and Policy of Global Change

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[**] Corresponding author (Department of Economics, Tufts University, Medford, MA 02155. gilbert.metcalf@tufts.edu)

A Note on Weak Double Dividends

Abstract

A weak double-dividend is the proposition that the welfare improvement from a tax reform, where environmental taxes are used to lower distorting taxes, must be greater than the welfare improvement from a reform where the environmental taxes are returned in a lump sum fashion. A general consensus has emerged that the weak double-dividend is an uncontroversial idea. We show in this note that a weak double-dividend need not hold in a world with multiple distortions.

I. Introduction

Environmental economists have focused a great deal of attention in recent years on the uses of revenues from environmental taxes. The potential for tax policies that reduce pollution while raising revenues that might replace other distortionary taxes holds great appeal for economists and policymakers alike. The potential for this dual role for environmental taxes has been incorporated in the idea of an environmental "double dividend." This is the idea that imposing an environmental tax can both improve economic performance and the environment. Goulder (1995) provides a useful taxonomy of double dividends as well as an explanation of the dividend's appeal.[1]

Economists have debated the existence of various forms of double dividends over the past decade. We refer readers interested in the history of this debate to Bovenberg (1999) and his excellent summary of the literature. Here we focus on what has been a relatively uncontroversial idea: the "weak" double dividend. A weak double dividend occurs when the welfare gain achieved by using the environmental tax proceeds to lower a distorting tax is greater than the gain achieved by distributing them in a lump sum fashion.[2] A general consensus has emerged that the weak double dividend holds.[3] In this note we show that in an economy with multiple distortions, a

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[1] See Bovenberg (1999) for an update to that literature.

[2] In contrast a "strong" double dividend is the case where implementing the environmental tax and using proceeds to reduce distorting taxes improves welfare without consideration of the environmental benefits arising from the tax.

[3] Starrett (1999) notes, for example, that "this result is quite general and reflects the fact that we are always better off using the green tax revenue to reduce some other distorting tax rather then [sic] (for

weak double dividend need not occur. Our argument is a standard second-best argument. In the presence of multiple taxes (other than environmental taxes), the use of environmental tax revenues to lower one tax (and hence reduce one distortion) may exacerbate a distortion arising from taxes in some other market. We illustrate this with a simple general equilibrium model that highlights the competing distortions in a particularly transparent way.

II. Model

In this section, we present a simple analytic general equilibrium model to show that the weak double-dividend need not hold. While the weak double-dividend will hold true in a world with only one (non-environmental) distorting tax, it will not necessarily be true in a more general economy.

Our model is particularly simple. There are two goods (X and Y), both of which are produced with labor (L). Good Y creates pollution (Z) as a by-product of the production process. As noted elsewhere (see Fullerton and Metcalf (2001)), we can model pollution as an input into the production process. Without loss of generality, we can also associate some labor with pollution. This simply assures an interior solution to the model:

(1) $$X = L_X$$

(2) $$Y = F(L_Y, Z)$$

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example) returning it in a lump sum manner." (p. 36) See also the discussion in Goulder (1995) on pages 159-161.

where F is a constant returns to scale production function. We assume that one unit of labor is associated with each unit of pollution so that the resource constraint is

(3) $$L = L_X + L_Y + Z$$

Utility of a representative agent is a function of consumption of the two goods, leisure (V) and environmental quality (E):

(4) $$U(X,Y,V;E) \quad \text{where } E=e(Z),\ e' < 0.$$

Consumers maximize utility subject to the budget constraint

(5) $$p_X X + p_Y Y = L + T$$

where p_X and p_Y are the consumer prices for X and Y, the gross wage rate equals 1 (labor is taken as the numeraire good) and T is a lump-sum transfer. Leisure and labor sum to a fixed time endowment. Consumer prices are related to producer prices as follows:

(6a) $$p_X = 1 + t_X$$

(6b) $$p_Y = q_Y(1+t_Y)$$

(6c) $$p_Z = 1 + t_Z$$

where t_x and t_z are commodity taxes levied on goods X and Y, respectively, to raise revenue, and t_z is an environmental tax, levied on Z. Given the technology, the producer prices of X and Z always equal 1 and we normalize the producer price of Y (q_Y) so that it equals 1 prior to the imposition of an environmental tax. The environmental tax is equal to zero initially. Consumer behavior can be represented by the following two equations under the assumption that L and E are weakly separable from each other and from (X,Y) and that utility over (X, Y) is homothetic[4]:

(7) $$\hat{X} - \hat{Y} = \sigma_c (\hat{p}_Y - \hat{p}_X)$$

(8) $$\hat{L} = -\varepsilon(\phi \hat{p}_X + (1-\phi)\hat{p}_Y)$$

where σ_C is the elasticity of substitution between X and Y in consumption, ε is the uncompensated labor supply elasticity and ϕ is the share of consumer expenditure on X. A hat over a variable indicates a percentage change. In other words, $\hat{X} = dX/X$.

(For taxes and transfers below, we will define $\hat{t} = dt/(1+t)$ and $\hat{T} = dT$.) Equation (7) says that substitution between X and Y depends on relative prices for X and Y and σ_C, while equation (8) relates labor supply to the real net wage. The nominal wage is 1 and the real wage equals the nominal wage divided by a price index based on the consumer prices of X and Y.

The government budget constraint is given by

(9) $$t_X X + t_Y q_Y Y + t_Z Z = T,$$

again noting that t_Z initially equals zero. Below, we discuss how taxes and transfers adjust to maintain equation (9) as the environmental tax is levied.

Finally, pollution abatement can be captured in the production function for Y by

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[4] These assumptions are commonly made as a "neutral" stance assumption.

(10) $$\hat{L}_Y - \hat{Z} = \sigma_Y \hat{t}_Z$$

where σ_Y is the elasticity of substitution between clean labor and pollution in production.

We consider three different experiments. In each, we introduce a small environmental tax ($\hat{t}_Z > 0$) and let one of the three following variables adjust endogenously: $\hat{T}, \hat{t}_X, \hat{t}_Y$. We can then compare the change in utility across policy changes. The change in utility in general is given by:

(11) $$\frac{dU}{\lambda L} = \left(\frac{t_X X}{L}\right)\hat{X} + \left(\frac{t_Y Y}{L}\right)\hat{Y} - \mu\left(\frac{Z}{L}\right)\hat{Z},$$

where λ is the private marginal utility of income and $\mu \equiv -\frac{\partial U}{\partial E}\frac{e'(Z)}{\lambda}$ is the social marginal damages of pollution.[5] The left hand side of equation (11) gives the change in utility in dollar terms $\left(\frac{dU}{\lambda}\right)$ as a percentage of the value of resources used in production (L). In other words, it expresses the dollar value of the utility change as a percentage of GNP.

Differentiating equation (5), we can obtain:

(12) $$\phi(\hat{p}_X + \hat{X}) + (1-\phi)(\hat{p}_Y + \hat{Y}) = S_L \hat{L} + \frac{\hat{T}}{L+T}$$

[5] Equation (11) is derived by totally differentiating the utility function, substituting in the consumer's first order conditions from utility maximization along with the total derivative of the resource constraint.

where $S_L \equiv \frac{L}{L+T}$. Differentiating equation (9) yields

$$\phi(\hat{t}_X + \theta_X \hat{X}) + (1-\phi)(\hat{t}_Y + \theta_Y(\hat{Y} + \hat{q}_Y) + \left(\frac{Z}{T+L}\right)\hat{t}_Z = \frac{\hat{T}}{L+T} \tag{13}$$

where $\theta_i = \frac{t_i}{1+t_i}, i = X, Y$. Next, we can differentiate the three price expressions in equation (6) to obtain

$$\hat{p}_X = \hat{t}_X \tag{14}$$

$$\hat{p}_Y = \hat{q}_Y + \hat{t}_Y \tag{15}$$

and

$$\hat{p}_Z = \hat{t}_Z \, . \tag{16}$$

Assuming firms set producer price equal to marginal cost,

$q_Y = MC = C(t_Z, Y = 1) \equiv \left(\frac{L_Z^*}{Y}\right) + p_Z\left(\frac{Z^*}{Y}\right)$ where L_Z^* and Z^* are the optimal (and observed) levels of labor input and pollution used in the production of Y. These equalities follow since the production function is constant returns to scale. Differentiating this equation, invoking the Envelope Theorem, and using equation (6b), we obtain

$$\hat{p}_Y = \hat{t}_Y + \left(\frac{Z}{Y}\right)\hat{t}_Z \, . \tag{15'}$$

Finally, we can differentiate the resource constraint (equation (3)) to obtain

(17) $$\hat{L} = \left(\frac{L_Y}{L}\right)\hat{L}_Y + \left(\frac{X}{L}\right)\hat{X} + \left(\frac{Z}{L}\right)\hat{Z}\,.$$

If we substitute equations (14), (15'), and (16) into equations (7), (8), (12), and (13), we can express the general equilibrium response in terms of tax changes rather than price changes:

(18) $$\hat{X} - \hat{Y} = \sigma_C\left(\hat{t}_Y + \left(\frac{Z}{Y}\right)\hat{t}_Z - \hat{t}_X\right)$$

(19) $$\hat{L} = -\varepsilon\phi\,\hat{t}_X - \varepsilon(1-\phi)\left(\hat{t}_Y + \left(\frac{Z}{Y}\right)\hat{t}_Z\right)$$

(20) $$\phi(\hat{t}_X + \hat{X}) + (1-\phi)\left(\hat{t}_Y + \left(\frac{Z}{Y}\right)\hat{t}_Z + \hat{Y}\right) = S_L\,\hat{L} + \frac{\hat{T}}{L+T}$$

and

(21) $$\phi(\hat{t}_X + \theta_X\,\hat{X}) + (1-\phi)\left(\hat{t}_Y + \theta_Y\left(\hat{Y} + \left(\frac{Z}{Y}\right)\hat{t}_Z\right)\right) + \left(\frac{Z}{T+L}\right)\hat{t}_Z = \frac{\hat{T}}{L+T}\,.$$

Equations (18) - (21) along with (10) and (17) are a system of six linear equations in six unknowns. The endogenous variables are $\hat{X}, \hat{Y}, \hat{L}, \hat{L}_Y, \hat{Z}$, and one of the following three variables $\hat{T}, \hat{t}_X, \hat{t}_Y$ while $\hat{t}_Z$ is the exogenous variable.

As we consider implementing a small tax on pollution ($\hat{t}_Z > 0$), we have a number of possible uses of revenues. Table 1 outlines the three policies we consider:

TABLE 1 ABOUT HERE

A weak double dividend occurs when the welfare gains from policies 2 or 3 are greater than the welfare gains from the first policy[6]. We next show that the weak double dividend need not hold.

III. Results

We impose a small environmental tax (starting at a zero tax rate) and solve the general equilibrium model described above and use equation (11) to measure the welfare impact of the policy. We note our parameter assumptions in Table 2. These parameter assumptions are based on Fullerton and Metcalf (2001).

TABLE 2 ABOUT HERE

Table 3 reports the welfare gains (or losses) for a small environmental tax with proceeds returned lump sum for various configurations of initial tax rates. We simulate an environmental tax rate equal to ten percent of the producer price of pollution $\left(\hat{t}_Z = 0.1\right)$. In general the tax is welfare enhancing unless the commodity tax on the polluting good is disproportionately larger than the tax on the non-polluting good. This follows since the pollution tax increases the cost of the polluting good and so increases the intercommodity distortion between goods X and Y that exists initially because of the commodity tax. Note that the welfare losses can result from the increased wedge between the prices of X and Y despite first-order gains from reduced pollution.[7]

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[6] Alternatively, the welfare loss from policies 2 or 3 are less than the welfare loss from policy 1.

[7] Higher levels of taxation on Y than X are not necessary to effect a welfare loss as Table 3 shows in the bottom right corner. High levels of overall taxation exacerbate the labor-leisure distortion and can also

TABLE 3 ABOUT HERE

Table 4 conducts a similar simulation in which the environmental taxes are used to lower taxes on X.

TABLE 4 ABOUT HERE

Again, the environmental tax raises welfare unless the polluting good is taxed more heavily than the non-polluting good. Note that the welfare change is constant so long as the two goods are taxed at the same rate. This follows because of our assumption of weak separability from leisure along with homotheticity. In such a case, the optimal tax is a uniform tax on commodities or equivalently a tax on labor in this model (see Deaton (1979)). Given the optimal construction of the tax system, the change in the tax on pollution has first order welfare effects only through changes in environmental quality.[8]

Next we compare the welfare gains from returning the environmental tax by lowering the tax on the clean good (X) versus increasing the lump-sum transfer.

TABLE 5 ABOUT HERE

A weak double dividend occurs in cases where entries in Table 5 are positive. This table is constructed by subtracting entries in Table 3 from the corresponding entries in

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bring about a welfare loss despite the environmental gains. These results illustrate the point by Sandmo (1975) that the optimal environmental commodity tax is a weighted average of a Ramsey component and an environmental component. As tax distortions increase, Sandmo observed, the weight on the Ramsey component rises. In this model, the Ramsey component pushes us towards uniform taxation of X and Y and any tax that deviates from uniform taxation would be welfare reducing.

8 $\frac{dU}{\lambda L} = \mu\left(\frac{L_Z}{L}\right)\hat{t}_Z = (.1)(.3)(.1) = .003$ or .3 percent.

Table 4. The first row is the usual case considered in the literature when there is only one distortionary tax on the non-polluting commodity. In this case, the weak double dividend holds. When the initial tax on the polluting good is sufficiently higher than the tax on the non-polluting good, however, a weak double dividend will not hold. In other words, it will be better to return the environmental proceeds lump-sum rather than use them to reduce distorting taxes.

Table 6 shows that this result is not due to the particular commodity tax chosen to be lowered in response to the environmental levy. Now we use the proceeds to lower the commodity tax on the polluting good.

TABLE 6 ABOUT HERE

Again, the weak double dividend fails if the environmental tax revenues are used to reduce the commodity tax on the good currently taxed at a lower rate.[9]

In general if the environmental tax revenue is used to reduce the differential between two distorting taxes then a weak double dividend occurs. If the recycling increases the difference between existing distortions then recycling is welfare worsening compared with lump sum recycling *even if it reduces an existing distortion* (here between leisure and labor). In other words, in an economy with multiple distortions one must choose carefully which distortions to reduce, or one can do worse than a lump sum redistribution. Put simply, there is no theoretical basis to conclude that a weak double dividend must exist.

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[9] These qualitative results hold over any reasonable range of estimates for parameter values in Table 2.

IV. Conclusion

We have shown in a simple analytic general equilibrium model that the weak double dividend does not hold unambiguously. Relative tax distortions play an important role in this result. Revenue recycling can be welfare worsening if it increases the relative distortion among goods *even if it reduces an existing distortion*. This suggests that a careful assessment of just which distortions to reduce is necessary or one can do worse than lump sum recycling. While this result is of theoretical interest, it turns out also to be of important practical interest. In Babiker, Metcalf and Reilly (forthcoming), we use a large-scale computable general equilibrium model to demonstrate that the weak double dividend is unlikely to hold for a number of European countries when policies are considered to reduce carbon emissions. Thus the results of this paper should be considered in discussions of international policies to combat global warming.

Table 1: Policy scenarios		
Policy	**Hold Fixed**	**Adjust**
1	t_X, t_Y	T
2	t_Y, T	t_X
3	t_X, T	t_Y

Table 2. Model assumptions		
σ_c		1.0
σ_Y		1.0
ε		0.4
μ		0.1
Initial Allocation	L_X	40
	L_Y	30
	L_Z	30
	Y	30

Table 3. Lump sum return of tax						
		t_X				
		0	0.1	0.2	0.3	0.4
t_Y	0	0.25%	0.32%	0.39%	0.47%	0.56%
	0.1	0.05%	0.13%	0.20%	0.28%	0.36%
	0.2	-0.15%	-0.07%	0.01%	0.09%	0.17%
	0.3	-0.35%	-0.27%	-0.19%	-0.11%	-0.03%
	0.4	-0.55%	-0.48%	-0.40%	-0.32%	-0.23%
Welfare impact of a new environmental tax for different initial tax rates on X and Y						

Table 4. Reduction in tax on clean good						
		t_X				
		0	0.1	0.2	0.3	0.4
t_Y	0	0.30%	0.60%	0.91%	1.24%	1.57%
	0.1	0.00%	0.30%	0.61%	0.94%	1.27%
	0.2	-0.32%	-0.01%	0.30%	0.62%	0.96%
	0.3	-0.64%	-0.34%	-0.02%	0.30%	0.63%
	0.4	-0.97%	-0.67%	-0.35%	-0.03%	0.30%
Welfare impact of a new environmental tax for different initial tax rates on X and Y						

Table 5. Weak double-dividend calculation						
		t_X				
		0	0.1	0.2	0.3	0.4
t_Y	0	0.054%	0.283%	0.520%	0.764%	1.019%
	0.1	-0.056%	0.174%	0.411%	0.655%	0.909%
	0.2	-0.172%	0.058%	0.294%	0.538%	0.790%
	0.3	-0.293%	-0.064%	0.172%	0.414%	0.664%
	0.4	-0.415%	-0.188%	0.046%	0.286%	0.534%
Welfare gain in case where environmental tax used to lower tax on X less welfare gain in case where environmental tax used to increase lump-sum transfer.						

Table 6. Alternative weak double dividend calculation						
		t_X				
		0	0.1	0.2	0.3	0.4
t_Y	0	-0.096%	-0.168%	-0.244%	-0.324%	-0.406%
	0.1	0.097%	0.024%	-0.053%	-0.132%	-0.214%
	0.2	0.296%	0.221%	0.144%	0.064%	-0.019%
	0.3	0.498%	0.423%	0.345%	0.264%	0.181%
	0.4	0.705%	0.628%	0.549%	0.468%	0.384%
Welfare gain in case where environmental tax used to lower tax on Y less welfare gain in case where environmental tax used to increase lump-sum transfer.						

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