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SECOND-BEST POLLUTION TAXES

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ABSTRACT

When government needs more revenue than is available from a pollution tax rate equal to marginal environmental damage, our intuition tells us to raise the tax on the clean good above zero and to raise the tax on the dirty good above that first-best Pigouvian rate. Yet new results suggest that the second-best pollution tax is below the Pigouvian rate. This note reconciles these views by pointing out that these new results use a labor tax to acquire additional revenue, and that the labor tax is equivalent to a uniform tax on both clean and dirty goods. Thus, depending on the normalization, the total tax on the dirty good can be above the Pigouvian rate. These recent results are meant to show that the *difference* between the tax on the dirty good and the tax on the clean good is less than the Pigouvian rate. Any one tax rate can be set to zero as a conceptual matter, but implementation of some taxes might be easier than others as a practical matter.

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Second-Best Pollution Taxes

With no revenue requirement, or where government can use lump-sum taxes, Arthur C. Pigou (1947) shows that the first-best tax on pollution is equal to the marginal environmental damage. Consumers then pay the social marginal cost of each item, the direct cost of resources plus the indirect cost of pollution.

Suppose government needs more revenue, however, and cannot use lump-sum taxes. In this second-best world, our intuition tells us to raise all tax rates: the tax on any "clean" commodity would be raised above its first-best level of zero, and the tax on a "dirty" good would be raised above its first-best Pigouvian level (the marginal environmental damage). Despite this intuition, a recent paper by A. Lans Bovenberg and Ruud A. de Mooij (1994) claims to "... demonstrate that, in the presence of preexisting distortionary taxes, the optimal pollution tax typically lies below the Pigouvian tax" (p. 1085).

This note argues that nothing is wrong with the intuition that all taxes would be raised. Nothing is wrong with the Bovenberg and de Mooij model either, but the above quote could be misinterpreted. I generalize their model to reconcile these opposing views.

Earlier writers have expressed several versions of the "double-dividend hypothesis."[1] These views are discussed more below, but an extreme version of this hypothesis might claim that the tax on the dirty good would rise even more than that on the clean good, because it can address the environmental problem *and* reduce the overall cost of tax distortions. The important and correct result of Bovenberg and de Mooij is that this extreme view is flawed.[2] Even if the pollution tax helps solve an environmental problem, it likely worsens other tax

[1] Examples include David Terkla (1984), Dwight R. Lee and Walter S. Misiolek (1986), and Wallace E. Oates (1991).

[2] Other recent literature that refutes this extreme view includes Bovenberg and F. van der Ploeg (1994), Bovenberg and Lawrence H. Goulder (1994), and Ian W. H. Parry (1995). Further discussion is provided by Oates (1995) and Goulder (1995), who distinguishes weak and strong forms of the double-dividend hypothesis.

distortions. Thus the tax on the dirty good would rise by less than the tax on the clean good. Bovenberg and de Mooij focus on the *differential* between the tax rates on the clean and dirty goods, but they never quite say so. They assume the tax on the clean good is always zero, so their dirt tax *is* the differential. With this choice of normalization, starting with the dirt tax at the Pigouvian rate, additional revenue would be raised by the labor tax while the dirt tax (differential) would fall.

However, other normalizations are equally valid and sometimes preferable. In their model, the extra labor tax is equivalent to a uniform tax on both goods. Thus, from the same starting point with the dirt tax at the Pigouvian level, an equivalent policy would raise both the commodity tax rates. The total tax on the dirty good would then exceed the Pigouvian level.

Bovenberg and de Mooij clearly understand this point, but their readers might not. Therefore the first purpose of this note is just to clarify the interpretation of their results. The second purpose is to explore the role of "normalization" in a model with tax rates on both goods and on labor. Any one tax rate can be set to zero, as a conceptual matter, but implementation of some taxes might be easier than others as a practical matter.

I. The Model

Bovenberg and de Mooij use a linear production technology where a unit of time can be retained as leisure V, or it can be supplied as labor L to produce the dirty good D, the clean good C, or government consumption G. The number of individuals is N, and labor productivity is h. They define units such that all unit production costs are one. Thus

$$hNL = NC + ND + G \tag{1}$$

Their second-best optimum may involve a tax on the dirty good at rate t_D and on labor at rate t_L. Here, I add the possibility of a tax on the clean good at rate t_C. The procedure is to look at a revenue-neutral change that leaves G unaffected. Differentiate (1), use $dG = 0$, and divide by N:

$$hdL = dC + dD \tag{2}$$

Household utility depends on choices of private goods, given the public good G and the level of environmental quality E. Thus households maximize:

$$U = u(C,D,V,G,E) \tag{3}$$

subject to their budget constraint:

$$hL(1-t_L) = C(1+t_C) + D(1+t_D) \tag{4}$$

Environmental quality is a function of the output of the dirty industry, $E = e(ND)$, where $e' < 0$. Define τ as the dollar cost of environmental damage per unit of the dirty output:

$$\tau = -\frac{\partial u}{\partial E} e'N / \lambda \tag{5}$$

Each household's consumption of D imposes cost on the utility of N households, converted into dollars when divided by λ, the marginal utility of income. As will be confirmed shortly, this τ at the first-best optimum is the Pigouvian tax rate.

In general, the government's second-best problem is to maximize utility by its selection of tax rates t_C, t_D, and t_L. At that second-best optimum, given the revenue requirement ($dG = 0$), there is no change that can raise utility.

Totally differentiate the utility function (3), use $dV = -dL$, and set dU equal to zero:[3]

(6) $$dU = 0 = -\frac{\partial u}{\partial V}dL + \frac{\partial u}{\partial C}dC + \frac{\partial u}{\partial D}dD + \frac{\partial u}{\partial E}e'NdD$$

Then use household first order conditions,[4] the definition of τ in (5), and the production frontier (2) to get:

(7) $$0 = ht_L dL + t_C dC + (t_D - \tau)dD$$

Consider three special cases. First, suppose $t_L = t_C = 0$. Either government has some other lump-sum source of revenue, or, by happy coincidence, the Pigouvian tax collects just enough revenue to finance G. Then (7) implies $t_D = \tau$. This first-best outcome confirms that τ in equation (5) is indeed the first-best Pigouvian tax.

Second, consider the case of Bovenberg and de Mooij where $t_C = 0$ and the revenue requirement means $t_L > 0$. Then (7) implies:

(8) $$t_D - \tau = -ht_L \frac{dL}{dD}$$

Thus the sign of dL/dD is crucial, and their paper devotes an entire section to it. They consider a small revenue-neutral change that would raise t_D and lower t_L. In brief, they note that any added tax on D is a partial consumption tax that raises the overall cost of consumption and reduces the real wage. It therefore affects the labor/leisure choice as well as the mix of C and D. The added t_D

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[3] I set $dU=0$ to characterize the second-best optimum, whereas Bovenberg and de Mooij use dU to discuss the effect on utility of reducing t_D below the first-best Pigouvian level. Both methods reveal whether t_D lies below τ, the marginal environmental damage, but the actual value of τ may depend on which point is evaluated. I am grateful to Gib Metcalf for pointing this out.

[4] First order conditions imply $\partial u/\partial C=\lambda(1+t_C)$, $\partial u/\partial D=\lambda(1+t_D)$, and $\partial u/\partial V=\lambda h(1-t_L)$.

must exceed the fall in t_L, to collect the same revenue. Because it is more distorting, they argue, the increase in t_D affects actual labor supply more than the equal-revenue reduction in t_L. Thus both D and L fall.

For present purposes, let's just accept the argument that dL/dD is positive. In this case (where $t_C = 0$), equation (8) means the second-best pollution tax lies below the marginal environmental damage ($t_D < \tau$).

Third, however, the same equation (7) can be employed to show the case where $t_L = 0$. In this case, t_C is used to raise the necessary revenue, and:

(9) $$t_D - \tau = -t_C \frac{dC}{dD}$$

Assuming no perverse revenue effects, and $t_L = 0$, revenue-neutrality requires that an increase in t_D be accompanied by a fall in t_C. Thus, dC/dD clearly is negative. As long as revenue needs mean that t_C is positive, then $t_D > \tau$, and the second-best pollution tax exceeds the marginal environmental damage. This result confirms our intuition that the dirt tax can help raise revenue.

More generally, equation (7) implies:

(10) $$t_D < \tau \qquad \text{iff} \qquad t_C < -ht_L \frac{dL}{dC}$$

In the on-going example, a revenue-neutral shift from labor tax toward dirt tax is likely to reduce D and increase C, but also reduce labor supply. Thus dL/dC is negative, and the critical threshold for t_C is positive. Bovenberg and de Mooij choose a value ($t_C = 0$) that lies below this threshold, so their second-best pollution tax lies below the marginal environmental damage. But the result could have gone either way. If the pre-existing t_C happens to equal $-ht_L dL/dC$, by coincidence, then the second-best pollution tax could exactly match τ.

II. Interpretations

The simple explanation for these results is that the labor tax is equivalent to a uniform tax t on both C and D. The budget constraint in (4) is the same whether labor income is multiplied by $(1\text{-}t_L)$, or all expenditures are multiplied by $(1+t)$, as long as $(1+t) = 1/(1\text{-}t_L)$. Government revenue is also unaffected by this switch. Start from the Bovenberg and de Mooij solution with $t_L > 0$, $t_C = 0$, and $t_D < \tau$. Then with no effect on any outcome whatsoever, any portion of the labor tax can be replaced by raising both t_C and t_D, until t_D matches or exceeds the marginal environmental damage.[5]

The alternative normalization can be used to help clarify Bovenberg and de Mooij. In equation (9), where $t_L = 0$, the result was $dC/dD<0$ and therefore $(t_D\text{-}\tau)>0$. Thus the dirt tax is indeed used to raise revenue. Bovenberg and de Mooij show that labor supply falls, however, so the production frontier means dC/dD is smaller than one (in absolute value). Thus, from (9), the revenue-raising *component* of the dirt tax $(t_D\text{-}\tau)$ is less than t_C. The reason is that while both taxes distort the labor-leisure choice, the already-higher t_D also distorts the consumption mix.

In personal correspondence, Bovenberg says "To avoid confusion, we probably should have said that 'optimal tax differentiation is less than the Pigouvian rule would suggest.' Our point is perhaps clearer in a model in which intermediate inputs pollute. In that case, the optimal pollution tax is always below the Pigouvian tax, since the optimal tax on clean intermediate inputs is always zero (Bovenberg and Goulder, 1994)."

Another interpretation is provided by an equation in Agnar Sandmo (1975) that can be slightly rewritten to express the total tax on the dirty good as

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[5] Ronnie Schöb (1994) makes a similar point, but uses separable indirect utility, Roy's Identity, Slutsky decompositions, Cramer's rule, and figures with iso-revenue lines and indifference contours. The point here is very simple: the labor tax in Bovenberg and de Mooij is the same as a tax on C and on D, which would raise t_D above τ.

a weighted average of a revenue-raising Ramsey term (R) and the marginal environmental damage (τ):

$$t_D = (1 - \frac{1}{\eta})R + \frac{1}{\eta}\tau \qquad (11)$$

where η is the marginal cost of public funds. With distorting taxes in the economy, a marginal dollar of revenue has a social cost that is more than a dollar ($\eta > 1$). Thus the environmental component (τ/η) is less than the Pigouvian rate (τ). Bovenberg and de Mooij use the labor tax to acquire additional revenue, so the revenue-raising term in (11) is zero. Then $t_D = \tau/\eta < \tau$. If instead the labor tax were zero, then R may be large and $t_D > \tau$. Interestingly, an increase in the distortionary effects of taxes means a higher η, more weight on the revenue-raising term, and less weight on the marginal environmental damage.[6]

What about the double-dividend hypothesis? Early writers used partial equilibrium models and often were not explicit about the experiment under consideration. In some cases, they had in mind a reform that would replace command and control regulation with a Pigouvian tax. If this switch provides the same environmental protection, with the same effect on product prices, it would raise revenue that could be used to reduce distorting labor taxes. Bovenberg and de Mooij agree this reform would raise welfare.[7] In other cases,

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[6] This interpretation, as suggested by a referee, appears in Bovenberg and van der Ploeg (1994). The higher marginal cost of public funds (η) means that all public goods are more expensive, including protection of the environment. Thus the tax system is used less for the environment and more to try to raise revenue efficiently.

[7] In the terminology of Goulder (1995) and Parry (1995), this reform would have only the positive "revenue-recycling" effect of reducing other distorting taxes, without the negative "tax-interaction" effect of reducing the real net wage. This reform is equivalent to the "weak" version of the double-dividend hypothesis: if an uncorrected externality is subjected to initial taxation, then welfare is higher if the revenue is used to reduce other distorting taxes than if it is returned to consumers lump-sum.

early writers may have had in mind an initial point that was suboptimal. If some taxes are more distorting than others, then a reform might well be able to increase a pollution tax, reduce a highly-distorting tax, and raise welfare. Bovenberg and de Mooij also do not intend to refute this general proposition. Instead, their main point is that the early use of partial equilibrium models often did not recognize that additional environmental taxes can raise product prices in a way that exacerbates labor supply distortions.

In this sense, early writers were correct to think that the tax on the dirty good could be increased in some circumstances, even perhaps above the marginal environmental damage, but wrong to think that it would necessarily be less distorting than other taxes.

Finally, alternative normalizations are useful as a practical matter. Some countries may have large labor taxes while others rely more on commodity taxes. Also, in terms of reform, some instruments are easier to implement than others. Indeed, many tax rate combinations can achieve the same second-best optimal quantities. Hence the plural in my title. For example, suppose political constraints or administrative costs prevent the authorities from taxing the polluting industry at all, so $t_D = 0$. No problem. By equation (7), just set

$$t_C = \tau \frac{dD}{dC} - ht_L \frac{dL}{dC} \tag{12}$$

To shift consumption away from D, this tax on C must be negative.[8] This solution works like a deposit-refund system, or withholding tax. If the waste-end tax is unenforceable (t_D must be zero), just raise the labor tax and give part of it back as a subsidy on clean consumption.

[8] To have the same effect on relative prices as the earlier tax on D, this solution must subsidize C. In the earlier case, denoted here by asterisks, the budget constraint was $hL(1-t_L^*) = C + D(1+t_D^*)$. Divide through by $(1+t_D^*)$ and call the result $hL(1-t_L) = C(1+t_C) + D$. Then the new t_L must be $(t_L^*+t_D^*)/(1+t_D^*)$, and $t_C = -t_D^*/(1+t_D^*)$.

This observation leads to one more refutation. One other version of the double-dividend hypothesis might claim that an environmental tax always leads to higher welfare than an environmental subsidy, because the revenue from a tax can be used to reduce other distorting taxes in the economy, while the environmental subsidy must be funded by *raising* other distorting taxes. Not so. This model shows that the two are equivalent. The tax on the dirty good raises its price, which reduces the real net wage and offsets the cut in the labor tax. Symmetrically, the subsidy to the clean good reduces its equilibrium price, which raises the real net wage and offsets the needed increase in the labor tax.

III. Conclusion

Bovenberg and de Mooij obtain the correct analytical results with their normalization where the tax on the clean good is zero, but they leave the impression that the tax on the dirty good always lies below the Pigouvian rate. Other normalizations have no effect on the equilibrium outcome, but they are very useful to help interpret these results. First, if the labor tax were zero, the total tax on the dirty good could exceed the Pigouvian rate. It is the difference between the tax on the dirty good and the tax on the clean good that is less than the Pigouvian rate. Second, even if the dirt tax were zero, the same second-best optimum can be achieved using a higher tax on labor and a subsidy to clean consumption. Finally, this last normalization is useful to show that environmental subsidies are really no different from environmental taxes -- even in terms of revenue -- since they achieve the exact same equilibrium. A waste-end tax may be difficult to enforce, because of illegal dumping, and it raises product prices in a way that reduces the real net wage. A subsidy to proper disposal can achieve the same incentives, and it reduces product prices in a way that *offsets* the effect of the extra labor tax needed to pay for it.

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