Environmental Levies and Distortionary Taxation: Comment

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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 might tell us to raise all tax rates: the tax on any "clean" commodity should be raised above its first-best level of zero, and the tax on a "dirty" good should be raised above its first-best Pigovian level (the marginal environmental damage). Despite this intuition, a recent paper by A. Lans Bovenberg and Ruud A. de Mooij (1994 p. 1085) claims to "... demonstrate that, in the presence of preexisting distortionary taxes, the optimal pollution tax typically lies below the Pigovian tax... ."

This note argues that nothing is necessarily wrong with the intuition that all taxes should 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 a strong version of this hypothesis might claim that a revenue-neutral switch toward a tax on the dirty good and away from taxation of clean goods can improve environmental quality *and* reduce the overall cost of tax distortions. By implication, this view might suggest that any additional revenue requirements should be met by raising the tax on the dirty good by more than taxes on clean goods. The important and correct result of Bovenberg and de Mooij is that this strong view is flawed.[2] Even if the pollution tax helps solve an environmental problem, it likely worsens other tax distortions. Thus, the tax on the dirty good should 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 Pigovian 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 Pigovian level, an equivalent policy would raise both the commodity tax rates. The total tax on the dirty good would then exceed the Pigovian 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

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[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 the strong view includes Bovenberg and F. van der Ploeg (1994), Ian W. H. Parry (1995), and Bovenberg and Lawrence H. Goulder (1996). Further discussion is provided by Oates (1995) and by Goulder (1995), who distinguishes weak and strong forms of the double-dividend hypothesis.

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.

In fact, I later reinterpret the model of Bovenberg and de Mooij to describe a case where production requires both a clean input and "emissions." This dirty input is difficult to monitor, because it is not purchased on the market. Enforcement is difficult, if midnight dumping is easy. Yet any one of these tax rates can be set to zero. Thus, the emissions tax can be entirely replaced by the equivalent combination of a subsidy to all clean inputs plus an additional tax on output. This "two-part instrument" provides the same changes in all relative prices, and thus the same outcome, as the emissions tax. And both parts apply to market transactions, with invoices to substantiate the tax due or the subsidy requested.

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:

$$(1) \qquad hNL = NC + ND + G.$$

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:

$$(2) \qquad hdL = dC + dD.$$

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

$$(3) \qquad U = u(C, D, V, G, E)$$

subject to their budget constraint:

$$(4) \qquad hL(1 - t_L) = C(1 + t_C) + D(1 + t_D).$$

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:

$$(5) \qquad \tau = -\frac{\partial u}{\partial E} e' N/\lambda.$$

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 Pigovian 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]

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

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

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

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 Pigovian tax collects just

[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 Pigovian 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 $\partial u/\partial V = \lambda h(1 - t_L)$.

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 Pigovian 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:

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

Thus, the sign of dL/dD is crucial, and their paper devotes an entire section to it. In order to get definitive results for the change in L, they assume that a subutility function for consumption goods $Q(C, D)$ is homothetic and weakly separable from leisure.[5] 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 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 us 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:

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

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 the intuition that the dirt tax can help raise revenue.

More generally, equation (7) implies:

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

In the ongoing 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 preexisting 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 $(1 - t_L)$, or all expenditures are multiplied by $(1 + t)$, as long as $(1 + t) = 1/(1 - t_L)$. Government revenue also is 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.[6]

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, $(t_D - \tau) > 0$. Thus, under this normalization, 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),

[5] In addition, to focus on the relevant externality and taxes, the framework assumes away any other distortions such as imperfect competition or government regulation.

[6] Ronnie Schöb (1997) makes a similar point.

the revenue-raising *component* of the dirt tax $(t_D - \tau)$ 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 Pigovian 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 Pigovian tax, since the optimal tax on clean intermediate inputs is always zero. (Bovenberg and Goulder, 1996)

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

$$t_D = \left(1 - \frac{1}{\eta}\right)R + \frac{1}{\eta}\tau, \tag{11}$$

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 Pigovian rate (τ). Interestingly, an increase in the government revenue requirement means an increase in the distortionary effects of taxes, a higher η, more weight on the revenue-raising term, and less weight on the marginal environmental damage.[7]

Because Bovenberg and de Mooij set $t_C = 0$, they use the labor tax to acquire additional revenue. The revenue-raising term in (11) is zero, so $t_D = \tau/\eta < \tau$. With this normalization, if government needs more revenue, the labor tax would rise while the dirt tax actually would fall.

If, instead, the labor tax were zero, then R in (11) may be large and $t_D > \tau$. With this normalization, both t_C and t_D are raised to acquire more revenue. Thus, the intuition described in my introduction just uses a normalization different from that of Bovenberg and de Mooij.

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 Pigovian 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.[8] In other cases, 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.

[7] 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.

[8] 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.

III. The Equivalence of Environmental Taxes and Subsidies

Finally, alternative normalizations are useful as a practical matter. Some countries may have large labor taxes (where the normalization of Bovenberg and de Mooij would be relevant), while others rely more on commodity taxes (where t_L is low and $t_D > \tau$). 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.

A. *No Need to Tax the Dirty Good*

In the first interpretation, as above, $Q(C,D)$ is a subutility function over two market goods. Suppose, however, that political constraints or administrative costs prevent the authorities from taxing the dirty good 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.[9] This solution works like an implicit deposit-refund system, or withholding tax. If the dirt 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.[10]

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 tax systems 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. Thus, the tax system with the subsidy to the clean good plus higher labor tax is equivalent in all respects to the tax system with the higher dirt tax and lower labor tax.

B. *No Need to Enforce Against Dumping*

In a second interpretation, $Q(C, D)$ represents the "technology" of household disposal. Then Q is a single consumption good, C represents the amount going into clean forms of disposal such as recycling or sanitary landfill, and D is the amount dumped illegally.[11] Instead of describing indifference curves between C and D, the $Q(C, D)$ function describes isoquants that show different combinations of clean disposal and dumping that are feasible and consistent with any given level of consumption Q; the rest of the model is unchanged. A difficult problem for policy makers (and for economists using enforcement models) is how to set the level of costly enforcement, the probability of detection, and the penalty for dumping (t_D). Results here suggest this problem can be entirely circumvented. An equivalent outcome can be achieved by adding a tax on all output Q (or equivalently, on labor) and a subsidy to proper disposal. This solution is an explicit, second-best deposit-refund system.

[9] 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 $t_C = -t_D^*/(1 + t_D^*)$.

[10] Labor L can be taken to represent all resources that can be sold in the market or retained for use at home. Then t_L needs to tax all income to be a withholding tax on all spending.

[11] Fullerton and Thomas C. Kinnaman (1995) use such a function to solve for the optimal tax on output and subsidy to clean disposal (deposit-refund system) in a first-best model. Results here show equivalence in a second-best model. In this case, the units convention means that it costs a dollar to purchase *and dispose of* one unit in the form of C, or a dollar to purchase and dispose of one unit in the form of D. If clean disposal is more expensive, a dollar on C yields less consumption.

C. *No Need to Monitor Emissions*

In a third interpretation, $Q(C, D)$ is a constant returns-to-scale production function. Utility depends on consumption of Q, but the optimizations above simply substitute into that utility function the firm's production of Q, which uses a clean input C and emissions D. These emissions may be solid, liquid, or gaseous. The firm buys each unit of C on the market for a dollar (or $1 + t_C$, gross of tax). Each unit of emissions also entails some private cost for removal, transport, and disposal. By the units convention above, a unit of emissions is defined as the amount that costs a dollar (or $1 + t_D$, gross of tax). The utility function also could be amended to add other goods that are produced using only the clean input (labor).

Suppose the economy starts with a labor tax to raise revenue. The additional Pigovian tax would apply to emissions, and Bovenberg and de Mooij show that the second-best emissions tax t_D is less than marginal environmental damage τ. This emissions tax has an "output effect" that raises the cost of production, reducing demand for the good, and a "factor substitution effect" that induces the firm to cut emissions per-unit output. But emissions are not a purchased input with an invoice to help monitor and enforce the tax. An equivalent "two-part instrument" would provide a tax on output (to get the output effect) and a subsidy to clean inputs (to get the factor substitution effect). Both of these apply to market transactions, with invoices. Since labor is already subject to tax, however, this "subsidy" to the clean input really just means a lower tax here than in other nonpolluting industries. The combination (t_L, t_D) can be replaced by a system with a lower rate of tax on clean inputs used in Q, plus an excise tax on Q.

IV. 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 Pigovian 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 Pigovian rate. It is the difference between the tax on the dirty good and the tax on the clean good that is less than the Pigovian 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 a tax system with an environmental subsidy may be no different from one with an environmental tax—even in terms of revenue—since they can 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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