10/12/03

Chapter 17: Environmental Taxes

> [*I*]*t makes perfect sense to tax good things less heavily and bad things heavily . . . we ought to reduce taxes on work, investment, and entrepreneurship, and increase them on pollution, waste, and greenhouse gas emissions . . .*
> --Jeff Hamond and Brian Dunkiel ("The Logic of Environmental Tax Reform in the United States," *the ecological economics bulletin*, 3 (3), 1998)

> [*E*]*nvironmental taxes typically exacerbate, rather than alleviate, pre-existing tax distortions . . .*
> --Lans Bovenberg and Ruud de Mooij ("Environmental Levies and Distortionary Taxation," *American Economic Review*, 84 (4), pp.1085-9, 1994)

17.1: Introduction

This chapter is a brief survey of a frontier area of policy analysis – how environmental taxes work when there are other taxes. The analysis has implications for other forms of regulation such as marketable allowances and command-and-control.

Organization. Section 17.1 reviews our earlier analysis of environmental taxes as corrective Pigovian taxes (and tolls). The section extends the inquiry to compare environmental taxes with ordinary taxes and consider the use of the tax revenue.

Section 17.2 considers the possibility of a "double dividend hypothesis," where environmental taxes work toward two social goals at the same time – reducing the environmental harm and offset other (distortionary) taxes.

Section 17.3 studies the interaction of environmental taxes with other taxes and the problem that increasing the use of environmental taxes may increase the distortionary costs of existing taxes.

Section 17.4 finds non-distortionary properties of environmental taxes. These properties make environmental taxes unusually efficient as a revenue source, but they can also lead to some problems of equity or fairness.

Section 17.5 identifies the policy problem as one of balancing efficiency and fairness goals.

In this chapter we study what happens to environmental taxes when there are other taxes. I'll divide the study into four stages:

1. A long early stage from about 1910 to 1990 when economists focused their attention on the "corrective" property of environmental taxes, with little attention to the effects of other taxes
2. A brief stage from about 1990 to 1994 when economists turned their attention to the possible benefits of environmental tax reform and a "double dividend"
3. A recent stage from about 1994 to the present writing when economists found problems with the double dividend and emphasized the distortionary costs of environmental taxes
4. An overlapping recent stage where economists found unusual non-distortionary properties of environmental taxes, along with a tradeoff of efficiency and equity

The stakes are high. Some of the analysis emphasizes the distortionary costs of environmental taxes and has led to policy recommendations with substantially more environmental harm than the corrected Pigovian levels we have been studying. Other analysis finds unusual non-distortionary properties of environmental taxes and suggests the reverse. These differences are not limited to recommendations about environmental taxes, but spill over to affect recommendations about command-and-control, marketable allowances and other forms of regulation. The differences make it worthwhile to study a difficult and complicated policy area. Moreover, if environmental taxes are to be used more, they could generate large revenues, in the $100's of billions annually, in this country alone.

The environmental taxes we will study in this chapter are really taxes on externalities. The externalities we will focus on are caused by producers—for example, by factories emitting smoke in the process of producing steel, or commuters causing congestion while driving cars and producing trips to and from work. The taxes we will study in this chapter are "per unit" (or proportional) taxes. A 7% sales tax, for example, is a per unit tax. You pay 7 cents for the first dollar of your purchase, and you pay 7 cents for next dollar you spend, and so on. Per unit taxes are easy to work with, because the tax revenue is just the tax (or more precisely the tax rate) times the number of units of the thing being taxed.

17.1: First Stage – The Corrective Property of Environmental Taxes

17.1.1: Corrective Pigovian Taxes

We are familiar with the first stage, because this has been the perspective of the earlier chapters. In the highway congestion model we studied a bridge toll, in the fisheries model we studied a landing tax, and in the smoke model we studied an emissions tax. In these three environmental problems of congestion, depletion, and pollution the toll or tax is set equal to its Pigovian level, the sum of the marginal environmental damages.[1] The Pigovian tax mirrors the marginal cost a driver, fisherman, or polluter imposes on others back onto himself. The idea is to create incentives for the producer of the externality to avoid the tax by reducing the excessive levels of environmental harm to their efficient levels. This reduction is often called **corrective**.

The environmental tax revenue can be used to finance government production of goods and services like highways, schools, national defense, maintenance of national parks, and research on vaccines, to decrease other taxes, to compensate those who bear the costs of pollution and other environmental harms, or it could be divided up and returned to everyone, as we did in the computer simulation of Chapters 8 and 9. But to focus on how environmental taxes correspond to wage rates and other factor payments (like rent for use of land), let's make an unrealistic assumption. We will assume, just for this section, that there are no government produced goods and services and no other taxes, so we don't have to worry about tax interaction effects. Once we see the parallel between an environmental tax and a wage rate, we will drop this unrealistic assumption. In later sections we will take into account the role of government in producing goods and services and the resulting need for the government to finance them with taxes. In this section we ask: "How do corrective Pigovian taxes correspond to wage rates (and other factor payments)?"

The short answer is that the corrective Pigovian tax corresponds very closely to a wage rate (or a payment for a factor of production). Then, when in the following sections we take into account the more realistic complication of the government's raising of tax revenue to finance publicly produced goods and services, we can explore how this correspondence changes, if at all.

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[1] Recall that an environmental or externality tax is a tax per unit of an environmental or external harm; a Pigovian tax is an environmental tax set equal to a special level – the sum of the marginal environmental damages.

Figure 17.1
The "Corrective" Pigovian Tax and Its Correspondence to the Wage Rate

(*i*) The labor market. The NSB is maximized with wage w and labor employed L_0. The predicted NSB is the shaded triangle.

(*ii*) The smoke "half-market." With no regulation, the predicted smoke emission is S_u and predicted NSB is area A - area B.

(*iii*) The smoke "half-market" corrected with the Pigovian tax $\hat{t}$. The predicted smoke emission is S_0, and predicted NSB is the shaded area.

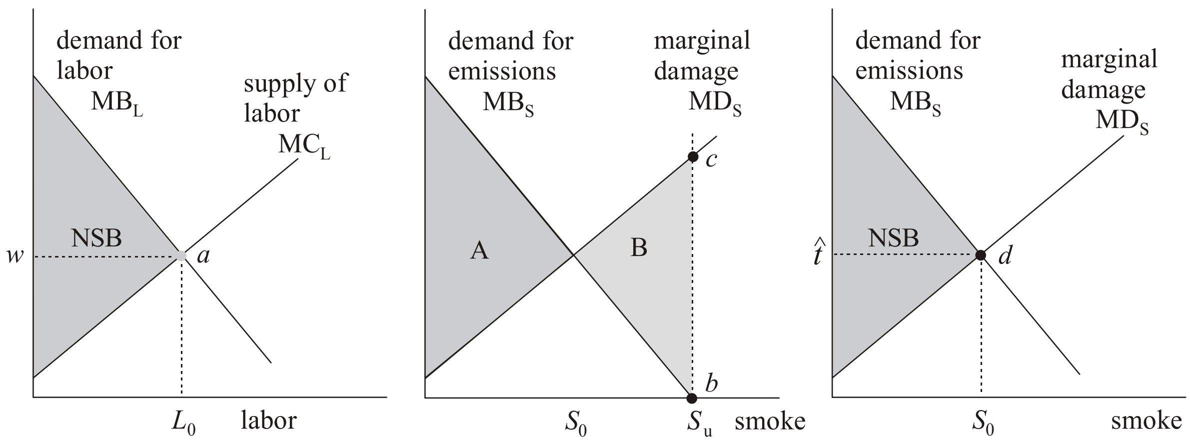


Figure 17.1 makes the comparison for the example of the steel industry, which produces steel by using labor and emitting smoke. Panel (*i*) shows the labor market for the industry. As in Chapter 6, the producers' demand curve for labor MB_L is the horizontal sum of each individual producer's marginal benefit curve (from labor), and the labor supply curve MC_L is the horizontal sum of each individual laborer's marginal cost curve. Here's a quick summary of the three market forces we studied in that chapter, applied to the labor market.

Box 1: Three Market Forces in a Well-Functioning Market for Labor

- **Producers' equalization.** On the demand side of the market, producers have an incentive to hire or lay off labor until the marginal benefit MB_L equals the wage rate *w*, which is the price producers have to pay for a unit of labor.
- **Laborers' equalization.** On the supply side of the market, laborers have an incentive to accept or reject job offers until the marginal cost MC_L equals the wage rate *w*, which is the laborers' rate of compensation for supplying a unit of labor.
- **Market clearing.** The wage rate adjusts until supply and demand pressures are satisfied for the same amount of labor employed in the industry.

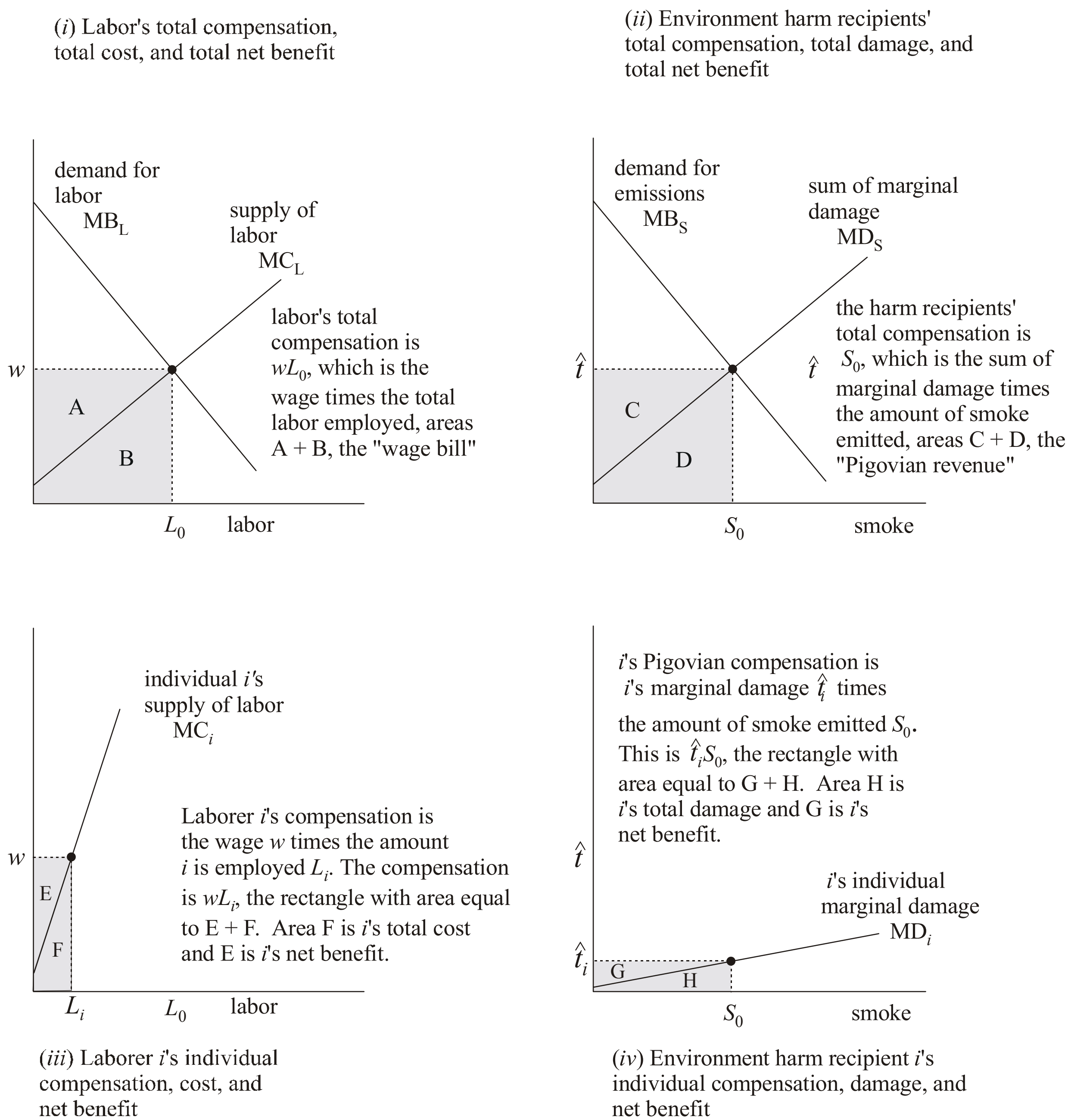
In the model of Figure 17.1(*i*) the three market forces are in equilibrium at *a*, for the wage *w* and employment level L_0. As you can see in the diagram, the net social benefit (NSB) attributable to the labor market is maximized for the amount of labor L_0 predicted in the model.

Panel (*ii*) shows the producers demand for smoke emissions. Smoke contributes to the production process, and if smoke is taxed or otherwise regulated, the producers will have to build expensive baghouses or undertake other expensive abatement or cut production of steel. The producers' demand for smoke emissions, MB_S, is the horizontal sum of each producer's marginal benefit from smoke. On the demand side, producers have an incentive to emit smoke up to the point where the marginal benefit MB_S equals the price the producers have to pay for a unit of emissions. In the unregulated situation, this price is zero, shown in panel (*ii*) at *b*. This part of the "market" is working in a corresponding way with the demand for labor in the labor market. By working I mean that the producers are equalizing their marginal benefits from smoke emissions to the price they pay for the emissions, corresponding to the producers' equalization in the labor market. The market incentive for the producers' equalization is working, but the zero price of emissions is inefficiently too low. In the unregulated situation the model predicts that the producers will, facing a zero price, emit smoke at the level S_u.

But the "market" is only half a market. As in Chapter 7, the curve of marginal damages MD_S is the vertical sum of the individual smoke recipients marginal damage curves (recall that the sum is a vertical sum because smoke is a public bad and harms many people at once). Because smoke is an externality, when there is neither compensation nor regulation as in panel (*ii*) the smoke recipients involuntarily live with the smoke that is emitted. The recipients may have costly individual defensive actions, for example moving to a less smoky location or buying air filters, and you can think of the underlying individual marginal damage curves as the net damage cost including the cost of "personal abatement actions." The model predicts that without compensation or regulation (and with Coasian bargaining impractical), producers will emit S_u at *b* and recipients marginal MD_S will be at *c* (panel (*ii*)). With only half a market, there are insufficient market incentives to make *b* and *c* coincide. Because smoke is an externality, there isn't a "recipients' equalization" corresponding to the laborers' equalization in the labor market. In panel (*ii*), area A represents the social benefits attributable to the smoke emissions and B represents the social costs, with the NSB = A – B. But NSB are maximized with smoke emissions S_0, and the predicted equilibrium is inefficient, a "market failure."

In panel (*iii*) the Pigovian tax fills in for the gap in effective incentives for the smoke recipients. The Pigovian tax $\hat{t}$, collected from the producers, raises the price of emissions for the producers and creates an incentive for producers to adjust their emissions to S_0. This half of the "market" works as it did before, but with a different price for the producers. As before, the other side of the "half-market" continues to lack equilibrating incentives. But with the government setting the environmental tax rate at $\hat{t}$ (pronounced "t hat"), the recipients' MD_S equals the producers' MB_S at *d* with the predicted emissions S_0 in panel (*iii*). With emissions at S_0, the NSB attributable to the smoke half-market is maximized and the externality is corrected, as we saw in Chapter 7.

Figure 17.2
Correspondence between Wage Compensation and Pigovian Compensation



Next we consider the correspondence between compensation to laborers in the labor market and compensation to harm recipients in the smoke half-market. In Figure 17.2(*i*), the laborers' total compensation is wL_0, the wage rate times the amount of employment, shown in panel (*i*) as the area A + B. This compensation, sometimes called the "*wage bill*," happens automatically in the market and goes directly to the workers. In corresponding situation with smoke corrected to its Pigovian level S_0, the amount of revenue generated is the Pigovian level of the environmental tax, which is the sum of the marginal damages or $\hat{t}$ times the amount of smoke S_0, and this is $\hat{t}S_0$. This amount equals the area C + D, the area of the rectangle with height $\hat{t}$ and length S_0, in panel (*ii*).

The government has to decide what to do with this revenue, which we call the Pigovian tax revenue, or **Pigovian revenue** for short. The case where the Pigovian tax corresponds most closely to the wage rate is where the government decides to use the Pigovian revenue to compensate the smoke recipients. In this case the Pigovian tax is like a wage rate, with the Pigovian revenue compensating the people who bear the costs of smoke, corresponding to the wage bill, which compensates the workers who bear the "time and trouble" of their labor.[2] Compensating the smoke recipients makes sense in another way as well. In this early stage of analysis, there is no need for revenue-raising taxes. In the case we are (briefly) considering there are no government produced goods and services.

Next we explore the correspondence between the Pigovian tax and the wage at the individual level. Panel (*iii*) of Figure 17.2 shows the curve of individual marginal cost of labor for individual *i* (his marginal cost is his "time and trouble" for an extra, small unit of labor). When he works L_i hours a day, his total cost of working is area F. His total compensation at the market wage rate is his wage w times his hours L_i, in other words wL_i, the whole rectangle E + F. His net benefit from working is E.

Panel (*iv*) shows the curve of individual marginal damage for individual *i* breathing smoke (his marginal damage is his health cost from breathing for an extra unit of smoke). His total damage from exposure to S_0 units of smoke is area H. In the diagram, he is compensated at the rate of his individual marginal damage $\hat{t}_i$. His total compensation is $\hat{t}_i S_0$, which is the rectangle with area G + H. His net benefit from exposure to the externality and being compensated for it is H. This corresponds to the labor market in which laborer *i*'s compensation E + F more than covers her total cost from labor F. In the environmental (externality) case, as courts put it, the (Pigovian) compensation makes the harm recipient "whole." Of course, when someone dies from an environmental harm, as with black lung disease[3], or an externality as in the World Trade

[2] But if people are compensated for environmental harms, will they have incentives to avoid the harm? Will there be too many people living too close to airports? This is the problem of "coming to the nuisance" we addressed in Chapter 16.

[3] Is black lung disease an externality? The disease, which is imposed by the work conditions in coal mining, fits our definition of an imposed harm that cannot be costly avoided. In a well-functioning market, this externality is in principle internalized by the bargaining process. But when laborers are not well informed of the risks and process of

Center bombing, one can't be made "whole." If you are "lucky," your family will be compensated at a rate roughly equal to the statistical cost of a life (somewhere between $1 to $3 million (as appears likely the case of the World Trade Center, but such compensation is unusual).

In principle, the correspondence between the Pigovian tax and the market wage is very close.[4] I say in principle because, even though some compensation is actually paid to people hurt by pollution and other environmental harms, it usually isn't. Even if the government wanted to pay harm recipients Pigovian compensation, as a matter of fairness or right, it is administratively impractical to compensate all the harm recipients at the rates equal to their individual marginal damages.[5] In contrast, in a well functioning labor market, the three market forces lead ("as by an invisible hand") the rate of compensation (the wage rate) to equal to the laborers' marginal costs of labor (per unit of labor time), as shown in panel (*iii*). We will address the problem of administrative feasibility for the environmental case toward the end of the chapter.

In summary, when the Pigovian tax is used to correct an environmental harm and the Pigovian revenue is used to compensate the harm recipients, on the basis of their individual marginal damages, the Pigovian tax corresponds directly to the wage rate (or other factor payments).

An important difference between the Pigovian tax $\hat{t}$ and the market wage w is that while the wage rate adjusts automatically to market forces, the Pigovian tax does not automatically adjust to the market but is set by the government. As a reminder of this difference I put a little hat over the Pigovian tax. In the 1950's and 60's when economists directed their attention to the corrective properties of the Pigovian tax, they often called it a "user fee" or a "charge" because it functions more like a wage than a tax (especially when the Pigovian revenue is used as compensation). Possibly a lot of confusion could be avoided if it were called a "Pigovian fee" or even a "Pigovian wage." But "Pigovian tax" is the common term now, and we will stick with that.

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the disease, or have little labor mobility, the health costs are unlikely to be fully internalized in the employment bargaining process.

[4] There remains the difference, though, that labor is a private good and the labor supply curve comes from adding the individual supply curves horizontally, while smoke is an externality where many people can be hurt at once and the MD_S comes from adding up the individual marginal damage curves vertically. This difference between horizontal and vertical adding explains the difference between panels (*iii*) and (*iv*). In panel (*iii*), L_i is less than L_0 and, in panel (*iv*), $\hat{t}_i$ is less than $\hat{t}$.

[5] It is too hard to estimate all the individual rates individually. It is easier to estimate the sum of the marginal damages $\hat{t}$ (with some error). The sum of marginal damages is often estimated in environmental damage assessments.

17.1.2: A Brief Introduction to Ordinary Taxes (We'll Need It Later)

It is often said that the only certainties in life are death and taxes. Now it is time to take into account publicly produced goods and services, and the need for revenue-raising taxes to finance them. Ordinary taxes are not "corrective" but "distortionary." For example, a tax on labor does not "correct" the amount of labor. In a competitive market, the level of labor was "correct" (efficient) before the tax on labor is imposed. Instead the labor tax "drives a wedge" between how much a worker values his or her labor and how much an employer values it.

Figure 17.3
Ordinary Distortionary Taxes--An Example with the Labor Tax

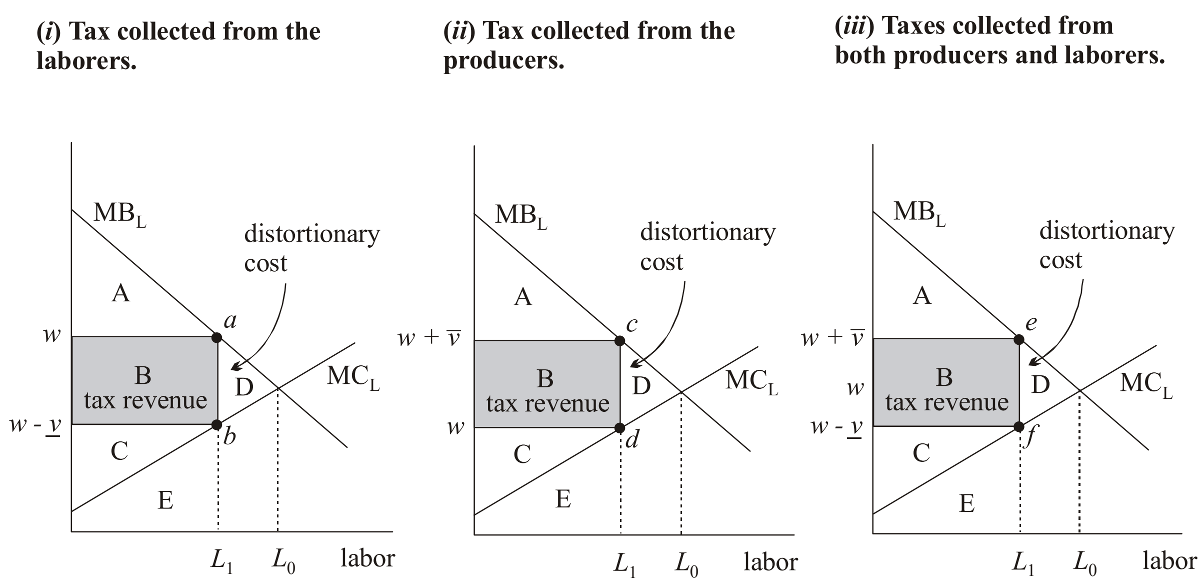


Figure 17.3(*i*) shows an ordinary xxx labor tax $\underline{v}$ collected from the laborers (this happens when laborers have to pay a payroll tax, or when laborers pay an income tax which we approximate by a tax per unit of work). With the tax, laborers' rate of compensation is their after-tax price of labor, $w - \underline{v}$, the market wage minus the tax they have to pay. Laborers have the incentive to seek or refuse employment up to the point where their after-tax rate of compensation equals their marginal cost MC_L.

Because in panel (*i*) the tax is not collected from the producers, their after-tax price of labor is just the wage rate *w*. As before producers have the incentive to hire or lay off labor up to the point where their after-tax price of labor equals their marginal benefit from labor MB_L (producers' equalization). As before, the wage adjusts until the amount of labor demanded by the producers is equalized to the amount supplied by the laborers (laborers' equalization). And in the supply-and-demand model, the wage rate adjusts until these equalizations happen, with labor employment at L_1 (market clearing).

In panel (*i*), producers equalize their marginal benefits to their after-tax price of labor at *a*, and the laborers equalize their marginal costs to their after-tax rate of compensation at *b*, for the same L_1. The effects of the three market forces described in Box 1 are shown by the corners of the rectangle B in panel (*i*). Geometrically the rectangle has its top right corner at *a* on the demand curve (producers' equalization), its bottom right corner at *b* on the supply curve (laborers' equalization), and *a* is vertically above *b* (market clearing). The area of the rectangle also has a meaning. Because its height is $\underline{v}$ and its length is L_1, the area is $\underline{v}L_1$. This is the tax revenue the government collects, the tax rate times the amount of labor employed.

The area of the little triangle to the right of the rectangle has a meaning too. The area is the net benefits that could be obtained if the government didn't need to impose a tax on labor to get the tax revenue to finance the publicly produced goods and services. This loss of net benefit is called the **distortionary cost** of the tax. To raise tax revenue, a tax is needed. But the tax leads to less labor employed (employment with the tax L_1 is less than employment L_0 without the tax).

With the tax, the whole area A + B + C + D is no longer the NSB attributable to labor employment. This is because the tax revenue B is used to finance public goods and services, or to reduce other distortionary taxes. The net benefits of these uses are likely to be higher than the amount of the tax revenue—otherwise it would not be worthwhile imposing the tax and creating the distortionary cost D.

The area A, though, is the net benefit to the producers of employing L_1 labor, when there is the tax $\underline{v}$, and the wage shifts because of the tax.

And area C is the net benefit to the laborers of supplying L_1 labor, when there is the tax $\underline{v}$ collected from the laborers (and the wage shifts because of the tax).

Think of the times you gone to a restaurant, looked over the menu and the prices, made your choice, enjoyed the meal, and then, when the bill came, saw the prices listed on the menu for your choices and just below an extra amount for the sales tax. The restaurant is collecting the tax from you to pass along to the government. The idea may have come to you, "Suppose the tax was collected from the restaurant rather than from me. The restaurant would mark up the prices to cover the tax and it would come to the same thing."

This intuition is perceptive, and panel (*ii*) of Figure 17.3 shows the same idea when the same amount of labor tax is imposed as in panel (*i*), except it is collected from the producers rather than from the laborers. In panel (*ii*) I wrote the tax $\bar{v}$ to remind us that it is collected from the producers rather than from the laborers.

The producers equalize their marginal benefits to $w+\overline{v}$, their after-tax price of labor at point *c*.

The laborers equalize their marginal costs to their after-tax rate of compensation *w* at point *d*.

The wage rate adjusts until the amount of labor demanded by the producers equals the amount supplied by the laborers, at L_1.

And the above three market conditions are met when the top right corner of the rectangle in Panel (*ii*) is at *c* and the bottom right corner is at *d*.

Is this L_1 in panel (*ii*) the the same amount of labor employed as the L_1 in panel (*i*)? I drew the MB_L and MC_L curves to be the same in the two panels. The amounts of the two taxes $\underline{v}$ and $\overline{v}$ are the same (but one is collected from laborers and the other producers), and so in both cases the height of the rectangle is the same. This means that the lengths of the two rectangles are the same—make an accurate drawing with the supply and demand curves the same as in panel (*i*) and the height of the rectangle equal to $\underline{v}$ (and also $\overline{v}$) and you will find there is only one way to get the corners on the supply and demand curves.

Thus the length of the rectangle is the same L_1 units long in both panels.

With the same height and length, the rectangles' areas are the same (so the tax revenues are the same).

With the same geometry, the producers' net benefits are the same in the two panels.

The laborers' net benefits are the same.

The distortionary costs are the same.

Moreover, after the wage has adjusted in the two situations, the after-tax compensation for labor $w-\underline{v}$ in panel (*i*) is the same as the after-tax compensation for labor *w* in panel (*ii*). This means that the after-tax labor compensation is the same in the two panels.

Panel (*iii*) shows what happens when taxes are collected from both producers and laborers, and the two taxes add up to the same total tax as in panels (*i*) and (*ii*). We get a different wage adjustment, but the same rectangle, and the same A, B, C, and D as before. Moreover, labor's compensation, which is the after-tax wage times the labor employment and equals the area C + E, is the same in all three panels.

This equivalence property applies to other ordinary taxes, besides labor taxes. Because this property will be useful later to distinguish a key difference between ordinary and environmental taxes, I'll highlight it here.

Box 2 : Equivalence Property for Ordinary Per Unit Taxes on Non-Externalities

If one tax $\overline{v}$ is imposed on the buyer and another tax $\underline{v}$ on the seller, the two taxes can be replaced with a single tax $v = \overline{v} + \underline{v}$, which could be imposed on either the buyer or the seller with the same equilibrium total amounts of the transaction, distortionary cost, tax revenue, buyers' net benefits, and sellers' net benefits.

17.2: Second Stage – The Double Dividend

Environmental taxes are mainly on things that society wants to discourage, like pollution, congestion, and depletion, while ordinary taxes are mainly on things society wants to encourage, like income.[6] Is it possible for environmental taxes to raise revenue for publicly produced goods and services (schools, roads, national defense) and at the same time discourage environmental harms? In Figure 17.2(*ii*) the Pigovian revenue was used to compensate environmental harm recipients, rather than to become a source of government revenue. This is the case where the Pigovian tax functions like a wage rate, but as economists have pointed out, it is impractical to compensate each harmed individual on the basis of his or her individual marginal damage. What would happen if the government kept some or all of the Pigovian revenue to finance publicly produced goods and services, or lower other taxes? This would be easier administratively. It would sacrifice compensation to the harm recipients, but it would be a source of government revenue.

In the early 1990's David Pearce and other environmental economists proposed a "green tax reform." The idea was to shift the tax base from ordinary taxes on things we want toward environmental taxes on things we don't want. Ordinary taxes have a single benefit—they raise government revenues. But they come with a major cost—they create distortionary costs. Environmental taxes have two benefits—they raise government revenues and at the same time correct environmental harms. A "double dividend" if you will. To take advantage of the double dividend, the idea goes, the tax base should be shifted toward environmental taxes. There should be more environmental taxes than there are now, fewer ordinary taxes, more revenue generated by environmental taxes and less by ordinary taxes. The shift does not need to be complete, but there is room for a substantial shift.

As far back as 1975, the Swedish economist Agnar Sandmo found a striking example of a double dividend. When government's revenue need equals the Pigovian

[6] This is not a complete difference because some ordinary taxes are "sin taxes," like taxes on cigarettes or alcohol, things that most people want to discourage.

revenue, the government's entire revenue need can be met by appropriating all the Pigovian revenue. All the ordinary (and distortionary) taxes can be set at zero with no distortionary cost to the tax system.[7] In this way the environmental tax corrects the environmental harm and raises revenue at the same time.

Policy makers found the idea of a double dividend appealing. In Europe and Japan the tax on gasoline is much higher than it is in the United States. An original motivation for high gasoline taxes was to raise revenue, and this revenue is a substantial fraction of the total tax revenue raised in Europe and Japan. High taxes are not popular, but when governments pointed out that the gasoline tax helped the environment, this tax became a less unpopular. The environmental effects of the gasoline tax were soon highlighted by the growing concern about climate change. Gasoline consumption releases large quantities of carbon dioxide, one of the main greenhouse gases. Other developed countries began to wonder when the United States would take the problem of global warming seriously and take the initial step of raising gasoline taxes. The pain of an increase in the gasoline tax is lessened because it would raise tax revenue and other taxes could be lowered (but many people directly feel an increase in the gas tax while not believing or noticing offsetting tax reductions elsewhere). European countries and especially Scandinavian ones began to explain energy taxes as beneficial to the environment and to make modest shifts in their tax systems toward environmental taxes.

17.3: Third Stage – Distortionary Costs of Environmental Taxes

17.3.1: The Tax Interaction Effect

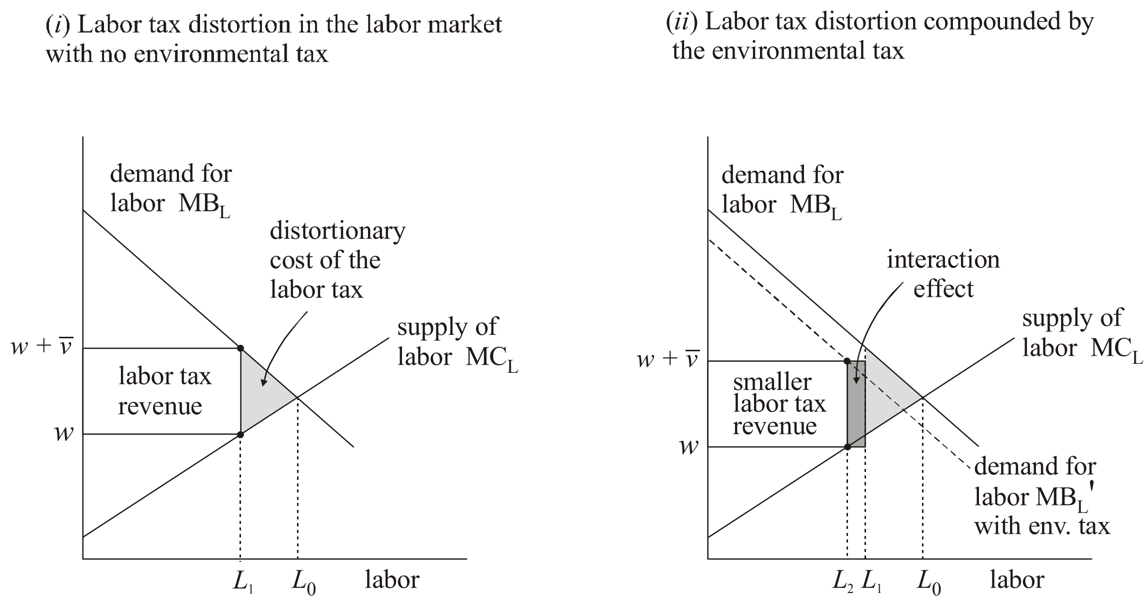
Public finance economists, who study how the tax system works, became interested in environmental taxes. They agreed with Sandmo's finding, but noted that almost always the government's revenue need is greater than the Pigovian revenue source, in which case there will be other taxes besides environmental taxes. While the public finance economists agreed that environmental taxes work strikingly well when there are no other taxes, they found a problem when there are other taxes. To see the problem, consider again the example of the steel industry, which uses labor and emits smoke.

Figure 17.4(*i*) shows the steel industry's labor market, when there is a tax $\bar{v}$ on labor (e.g. collected from the producers, as a withholding tax) and initially smoke is unregulated. As before the producers' demand for labor is MB_L, and the laborers' supply MC_L, and the distortionary cost of the labor tax is the shaded triangle, with equilibrium

[7] Agnar Sandmo noted this case in 1975 (Agnar Sandmo, "Optimal Taxation in the Presence of Externalities," *Swedish Journal of Economics*, pp. 86-98, 1975), but his observation did not receive much attention at the time.

labor employment L_1. Now consider what happens to the labor market when an environmental tax is used to reduce the smoke emissions. (The environmental tax could be set at its corrective Pigovian level, or some other level.)

Figure 17.4
The Tax Interaction Effect



Panel (*ii*) shows the effect in the labor market to regulating smoke by the environmental tax.[8] In response to the increased price of smoke, steel producers reduce their smoke emissions. They do this by reallocating some labor from direct steel production to building and maintaining bag houses and other means of smoke abatement. The producers may also reduce their steel production, and thereby smoke emissions with the reduction. These actions lead to social benefits of cleaner air, but they reduce the private benefits to the industry from making and marketing steel. With lower private benefits, and typically lower private *marginal* benefits, the producers' demand curve for labor is pushed downward to MB_L' as shown by the dashed line in Figure 17.4(*ii*).

Exercise (1). Draw diagrams to show what happens when

(a) the tax $\bar{v}$ on labor gets smaller

(b) the tax on labor is zero

(c) there is a tax $\underline{v}$ on labor, collected directly from the laborers

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[8] Panel (*ii*) is similar to a diagram by Goulder (p 402 in "Environmental Policy Making in a Second-Best Setting," in *Economics of the Environment*, (ed. Robert Stavins, 4th edition), W.W. Norton & Company: New York, 2000).

In Figure 16.4(*ii*), with the demand curve pushed down the wage adjusts downward a little and labor employment is further distorted from L_1 to L_2. Moreover, the distortionary cost in the labor market increases by the amount shown by the shaded rectangle. This increase in distortionary costs is what public economists mean when they say that environmental taxes "exacerbate" or "compound" the distortionary costs of pre-existing taxes. The increase in distortionary costs represented by the rectangle is called the **tax interaction effect**.

If environmental taxes exacerbate the distortionary costs of pre-existing taxes, and this effect is substantial, then environmental taxes and environmental tax reform are likely to lose some of their appeal. Further, it appears that the same interaction effect applies to other forms of regulation such as command-and-control and marketable allowances. If these forms of regulation are used, polluters are likely to respond by shifting labor into abatement. This leads to declines in the marginal private benefits to the polluters with a similar shift of the labor demand curve downward, as in Figure 17.4(*ii*). With the labor demand curve shifted downward by these other forms of regulation, there will be an increased distortion in labor employment and an increase in the distortionary cost of the labor tax. Not only is the total distortionary cost higher with the environmental tax (and possibly other environmental regulation) in panel (*ii*) than without it in panel (*i*), but also you can see that with the environmental tax, the labor tax revenue is smaller when there is an environmental tax than when there isn't. So the argument goes. Once these effects of environmental taxes and other forms of environmental regulation on pre-existing taxes are taken into account it seems that this will lower the appeal of environmental regulation generally, leading to lower levels of environmental protection generally.

How important is the interaction effect compared with the corrective benefits of environmental taxes and their revenue-raising opportunities? To answer this question, public finance economists used an approach similar to the one we used in studying externalities.

17.3.2: The Second-Best Problem

To find the most efficient[9] highway toll, we maximized the NSB, taking into account the "natural tendency" of to switch between the congested bridge and uncongested highway until the travel costs, the bridge toll for the bridge drivers, are

[9] Recall our second definition of efficiency: **efficiency** $= \frac{\text{actual NSB}}{\text{maximum possible NSB}}$. If there is uncertainty, we use "predicted NSB" rather than "actual NSB."

equalized between the two routes. (This is the idea of a Nash equilibrium and what Pigou called the "natural tendency.")

To find the most efficient combination of environmental and ordinary taxes, public economists do a similar maximization, but with more taxes and more constraints. Here's the approach:

Box 3: The Second-Best Problem

(1) find taxes that maximize the Net Social Benefit (NSB)

- where the NSB is the
  --benefits of market produced goods and services, plus
  --benefits of the publicly financed or produced goods and services, minus
  --distortionary costs of the tax system, and minus
  --costs of the environmental (externality) harms
- subject to
  --constraints of the market equilibrium conditions, and
  --constraints on the taxes; and then

(2) recommend these maximizing taxes as "second-best efficient taxes"

The recommended maximizing taxes are called "second-best" because of the constraints. With fewer constraints it typically is possible to find a higher NSB. Constraints of market equilibrium conditions include the producers' equalization, the laborers' equalization, and market clearing. The idea is that the government sets the taxes on a market economy, and the market equilibrium conditions arise from the incentives in the market process, if there are no uncorrected externalities or other sources of market failure (like monopoly pricing).

When there are taxes, the three market constraints lead to the tax wedge in Figure 17.3. The tax wedge is the rectangle in the diagram, creating both the tax revenue and the distortionary cost for ordinary taxes.

Why should policy makers put constraints on the taxes? Sometimes the taxes are constrained so that the total revenue they raise is fixed. This reflects what legislators and presidents mean when they say "no new taxes" ("no net increase in tax revenues").

If policy makers did not constrain their choice of taxes, second-best analysis would rely on some simple non-distortionary taxes. In doing so they could increase the NSB over what can be achieved by using ordinary distortionary taxes like income taxes, labor taxes, and sales taxes. Here's an example of these simple taxes. Everyone over 20 years old must pay an annual tax of $5000, no matter if he or she is rich or poor, healthy or sick. No one can change their behavior to avoid or lessen the tax (for the example we assume that the government keeps careful records of everyone's birth certificate, so no one can fraudulently claim a younger age). With no one able to modify their behavior to avoid these taxes, the taxes do not distort behavior and have no distortionary costs. So this argument goes. Taxes that you cannot avoid by changing your behavior are called **lump-sum** taxes.

If the lump-sum taxes are sufficient to meet the revenue need, they can replace all other taxes and the tax system will have no distortionary costs at all. The NSB will be higher than with ordinary distorting taxes and the outcome is called **first-best efficient**. Sandmo's example of the double dividend, where the Pigovian revenue replaced all other taxes, leading to no distortionary cost to the tax system, is another example of first-best efficiency. When we focused on the corrective properties of environmental taxes, and temporarily assumed that there were no government revenue needs and no taxes, we had another example of first-best efficiency. In diagrams of this chapter, the little 0 in L_0 and S_0 is for "first-best (optimal) efficiency."

If there are no constraints in the second-best analysis on lump-sum taxes, second-best analysis recommends increasing them to the point where they finance the entire revenue need. If some lump-sum taxes are allowed, but not enough to meet the revenue need, there will be some ordinary taxes to cover the shortfall in government revenue need. With these ordinary taxes there will be distortionary costs, and thus some distortionary costs to the tax system as a whole. But with more lump sum taxes and fewer ordinary taxes, the distortionary costs of the tax system as a whole will be lower, the NSB higher, and with higher NSB there will be a higher "second-best efficiency."

But there is an obvious problem with these lump-sum taxes. If you are poor, a \$5000 annual tax will be very burdensome. If you are very rich, a \$5000 tax will be hardly noticeable. And what happens if a poor 20 year old can't pay the \$5000 tax? Does he or she go to debtors' prison? Policy makers can avoid some of these adverse distributional consequences by setting lower taxes to poorer adults and higher taxes to richer adults. But then someone on the boundary between the lower and higher tax could modify his behavior, by working a little less to get into the lower tax category and the tax would become distortionary, like an ordinary tax (and they wouldn't be lump-sum, unavoidable taxes anymore).

Given the choice between using lump-sum taxes with their adverse distributional consequences and not using lump-sum taxes with their higher NSB and efficiency, policy makers almost always choose not to use lump-sum taxes. Most economists agree with this choice, and second-best analysis almost always includes the constraint "no lump sum taxes."

We have seen this idea before. In making decisions with streams of benefits and costs over generational time, we considered two policy goals: intergenerational efficiency (achieved by maximizing the present value of the net benefit stream over generational time) and intergenerational equity (achieved by choosing a "fair" distribution of benefits and costs over generational time). We considered balancing these two goals by maximizing the present value of the net benefit stream, subject to a constraint of sustainability. Similarly, the second-best approach balances the goals of efficiency and equity (here equity is the distributional fairness of the tax burden) by maximizing a NSB subject to a constraint on the choice of taxes ("no lump-sum taxes"). Clearly, in the policy debate much depends on the choice of the constraints chosen by the policy maker.

With this idea of constrained maximization in mind, we can now understand how the public finance economists estimated second-best environmental and ordinary taxes. They maximized the NSB over different possible choices of environmental and ordinary taxes with the constraints of the market equilibrium conditions and the constraint of no lump-sum taxes. They maximized the NSB (subject to these constraints) over all the markets and in this way took into account interactions across markets and their tax interaction effects. What they found was surprising. Typically they found that the second-best environmental tax is less than its corrective Pigovian level. Often it is about 35% less, sometimes more than that and sometimes less than that, but rarely as high as the Pigovian level.

Figure 17.5
The Second-Best Environmental Tax and the Second-Best Amount of Harm

Economists found that the second-best tax t_1 is typically lower than its Pigovian level $\hat{t}$ and the second-best amount of harm S_1 is typically higher than the Pigovian level S_0 of environmental harm. They found that increasing the second-best environmental tax t_1 a little bit decreases the distortionary cost A but this is offset by tax interaction effects.

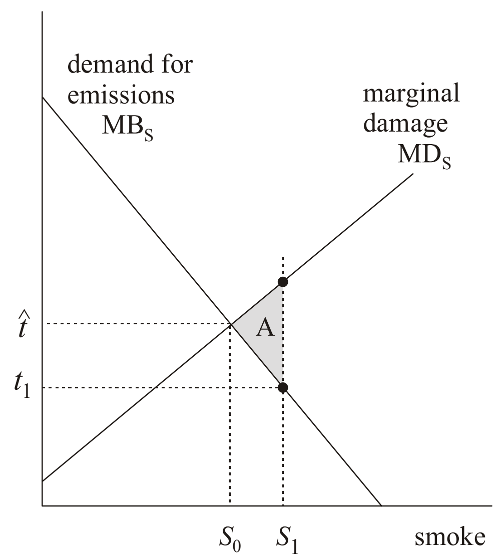


Figure 17.5 shows a second-best tax t_1 on smoke about 35% less than its corrective Pigovian level $\hat{t}$. With the lower environmental tax, the second-best level of smoke S_1 is substantially higher than its first-best level S_0. Area A shows the distortionary cost from the increased level of environmental harm (it comes because the marginal environmental damages of smoke are greater than the marginal benefits, when smoke increases above S_0). But, in the finance economists' analysis, this distortionary cost is made up for by reductions in the costs of tax interaction effects in other parts of the economy.

A theme in much of the recent literature is that "environmental taxes exacerbate pre-existing tax distortions." The idea is that with lower environmental taxes (and more environmental harms), there is less distortion of other taxes.

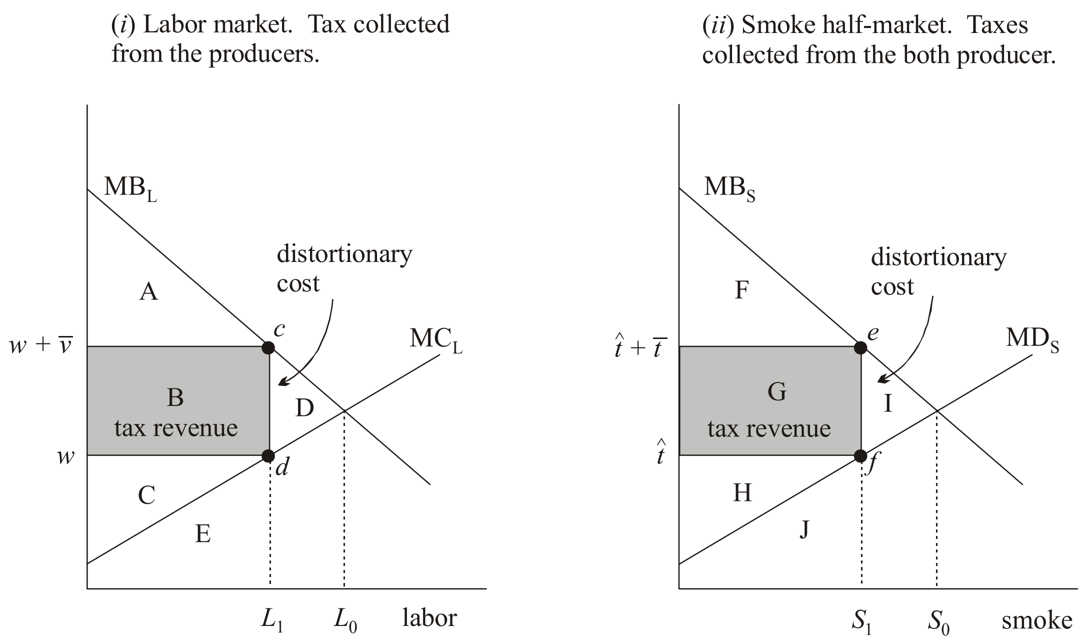
17.4: Fourth Stage – Non-Distortionary Properties of Environmental Taxes

17.4.1: Symmetry between Environmental Taxes and the Labor Tax

It seems strange that environmental taxes can be so non-distortionary in Sandmo's example, and so distortionary when there are other taxes. Granted that with the presence of other taxes there are tax interaction effects, but can there be non-distortionary properties of environmental taxes even when there are other taxes? There still seems to be a puzzle.

Let's take another look at Figure 17.1 and recall the situation when an environmental tax is set at its corrective Pigovian level $\hat{t}$, the Pigovian revenue is used as compensation for the smoke recipients, and there are no other taxes. In this case there was a symmetry between the environmental tax and the wage rate. Now let's add the complication of other taxes. Is there still a symmetry?

Figure 17.6
Symmetry between the Environmental Surtax and the Labor Tax



There is a symmetry, in fact two symmetries. One symmetry is between the wage and the Pigovian tax part of the environmental tax, and the other symmetry is between the labor tax and the remaining part of the environmental tax. Figure 17.6 shows the situation. In panel (*ii*) the environmental tax is divided into two parts: the Pigovian tax $\hat{t}$ which is collected from the producers of smoke and used as compensation for the smoke recipients, and an environmental "**surtax**" $\bar{t}$, which is also collected from the producers but used as ordinary tax revenue to finance publicly produced goods and services or substitute for other taxes.

In panel (*i*) the wage *w* is paid by the producers and used as compensation to the laborers. The labor tax $\bar{v}$ is collected from the producers and becomes a government source of tax revenue. Thus in the diagram the wage *w* corresponds to the Pigovian tax $\hat{t}$

and the labor tax $\bar{v}$ corresponds to the environmental "surtax" $\bar{t}$. In the diagram there are the two symmetries, but how do we know the diagram is drawn correctly?

Panel (*i*) of Figure 17.6 is the same as panel (*ii*) of Figure 17.3. The idea there was that producers hire and layoff until their after-tax price of labor ($w+\bar{v}$) equals their marginal benefit from labor, at *c*, the laborers seek and quit jobs until their after-tax price of labor (the wage rate *w*) equals their marginal cost of supplying labor at *d*, and the wage adjusts until the market clears with the same employment supplied as demanded (L_1). This much is standard economic analysis.

In panel (*ii*) of Figure 17.6 the smoke half-market of smoke producers emit smoke until their after-tax price of smoke ($\hat{t}+\bar{v}$) equals their marginal benefit from smoke at *e* and emissions level S_1. In the half of the market that is not working properly because of the externality, the smoke recipients live with the amount of smoke emitted. At this emissions level S_1 the sum of the marginal damages at *f*, just the Pigovian level of $\hat{t}$. This is not a surprise because the government sets the Pigovian part of the tax to equal the sum of the marginal damages (for the emissions level S_1 the smoke recipients are exposed to). So the lower right corner of the rectangle in panel (*ii*) is on the recipients' marginal damage curve at *f* and the diagram is drawn correctly.

For convenience, I have drawn the producers' demand curve for labor MB_L in panel (*i*) to look like the producers' demand curve for smoke emissions MB_S in panel (*ii*), the laborers' supply curve MC_L to look like the recipients' marginal damage curve MD_S, and the amount of the labor tax $\bar{v}$ to be the same amount as the surtax $\bar{t}$. With the symmetry, this makes area A the same as area F, and so on. In particular, the labor tax revenue (area B) equals the surtax revenue (area G), and the labor compensation (areas C + E) equals the smoke recipients' compensation (areas H + J). When the supply, demand, and damage curves differ, or the labor tax differ from the surtax, the two panels will look different, but the symmetry remains between wage *w* and the Pigovian tax, and between the labor tax $\bar{v}$ and the surtax $\bar{t}$.

The symmetry means that when there are ordinary as well as environmental taxes and when the Pigovian revenue is earmarked for compensation to the smoke recipients, the surtax behaves symmetrically like ordinary taxes in second-best analysis.[10] When there are both environmental and ordinary taxes in the economy, second-best ordinary taxes, like labor taxes, sales taxes, and income taxes are typically positive. Because of

[10] You can't really tell this from the diagrams and the intuitive discussion, but a graduate student Qinghua Zhang and I were able to derive the symmetry analytically in second-best analysis when there are multiple taxes (Page and Zhang, Economics Department Working Paper 2000-&&).

the symmetry, second-best environmental surtaxes are also typically positive (when the Pigovian revenue is used as compensation to the smoke recipients).

Panel (*ii*) of Figure 17.6 was not drawn for an optimized second-best surtax, but it shows what happens when the second-best surtax is positive. The positive surtax means that the producers' after-tax price is higher than the Pigovian level and the second-best level of smoke is lower than the Pigovian corrective level, shown by S_0 in the diagram. This is good news for many environmentalists, who like to see less pollution, rather than more.

What about the interaction effect? Analysis of the symmetry case reveals many tax interactions. Just as increasing the environmental tax compounds the distortionary cost of the labor tax, increasing the labor tax by itself compounds the distortionary cost of the smoke surtax. The tax interaction effects are reciprocal and even sometimes completely offsetting.

But why then did economists find that the second-best environmental tax was typically less than its Pigovian level (as in Figure 17.5)? The answer is that they were analyzing the asymmetric case where the Pigovian revenue is used as general revenue rather than for compensating the harm recipients.

Thus we find that a basic policy question is "Are there reasons for constraining second-best maximization to require the Pigovian revenue be used as compensation?" If the constraint is added, second-best analysis typically recommends a positive surtax and less environmental harm than its Pigovian corrected level. If the constraint is not added, second-best analysis typically recommends a negative surtax and more environmental harm than its Pigovian level. Moreover, this difference affects policy choice for other forms of regulation, like command-and-control. The difference could be substantial. As a rough guess there might be 50% or even 100% more "smoke" (environmental harms) when the constraint is not added compared with the situation when it is added (assuming that policy makers follow the recommendations of second-best analysis).

Figure 17.7
The Second-Best Environmental Tax
with and without the Constraint of Pigovian Compensation

The shape of the producers' demand curve MB_S reflects declining marginal benefits of smoke emissions and magnifies the difference in the recommended levels of smoke.

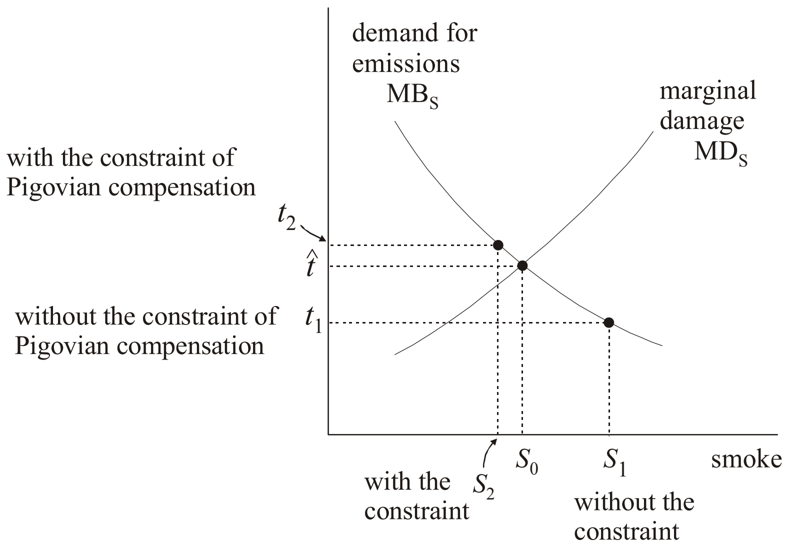


Figure 17.7 shows where this guess comes from, taking into account that the marginal benefits of smoke emissions are typically declining. Without the constraint that the Pigovian revenue is used as compensation to the harm recipients, economists found the second-best level of the environmental tax t_1 often to be about 35% less than its Pigovian level $\hat{t}$ as shown in the diagram. With this tax, we predict S_1 emissions of smoke.

When the Pigovian revenue is constrained to be used as compensation to the harm recipients, we are in the symmetry case. In this case, we are likely to get a second-best surtax positive. As a rough guess it might be about 10% of the Pigovian level. In this case the whole environmental tax t_2 would be about 10% more than the Pigovian tax, as in the diagram, and predicted smoke emissions would be S_2 as illustrated in the diagram. In the diagram smoke without the constraint (which requires the Pigovian revenue to be used as compensation to the recipients of the environmental harm) S_1 and this amount is is about 70% more than the smoke emissions S_2 with the constraint.

There are reasons for and against adding this constraint. Environmental legislation includes the distributional goal of an "adequate margin of safety" to protect the most vulnerable (this is stated in the Clean Air Act, for example). Requiring the constraint of Pigovian compensation provides a larger margin of safety, and the Pigovian compensation is targeted on the most vulnerable.

There is another and much more surprising reason. Qinghua Zhang and I found that when the Pigovian revenue is appropriated as an additional tax revenue source, it behaves equivalently like a lump-sum tax. The equivalence property is a formal mathematical property, but it means that the appropriated Pigovian revenue has distributional effects paralleling those from "ordinary" lump-sum taxes. This means that without a constraint requiring the Pigovian revenue to be used as compensation the environmental harm recipients, there are adverse distributional consequences analogous to the ones from lump-sum taxation. (The adverse distributional effects are the especially heavy burdens borne by those most vulnerable to the environmental harms, for example those with asthma are likely to bear especially heavy burdens from air pollution.) If the adverse distributional effects of "ordinary" lump-sum taxes are ruled out by constraint, why shouldn't the parallel adverse distributional effects of appropriating the Pigovian revenue be similarly ruled out by constraint of the environmental harm? Or by a constraint requiring compensation? Another reason for constraining the government is fairness or rights. Many people believe that the air and other environmental resources are (or should be) common property resources, and thus when a factory uses the air for waste disposal, the firm should compensate the true owners.

A reason against requiring Pigovian compensation is its impracticality. It may be possible to compensate some of the most vulnerable, and there are examples of this happening. But is seems administratively impossible to compensate everyone on the basis of their marginal damage. This is a strong practical argument. If there are adverse distributional consequences from the government's appropriating the Pigovian revenue, but Pigovian compensation is administratively infeasible, policy makers may have to look for some other way of limiting the adverse distributional consequences besides requiring Pigovian compensation.[11] Another way of protecting the vulnerable is to reduce the environmental harm in the first place. This option for reducing adverse distributional effects points toward setting the environmental tax higher than a policy maker would for just efficiency reasons.

To understand these policy options better we need to look more carefully at the "adverse distributional consequences" and more feasible alternatives to Pigovian

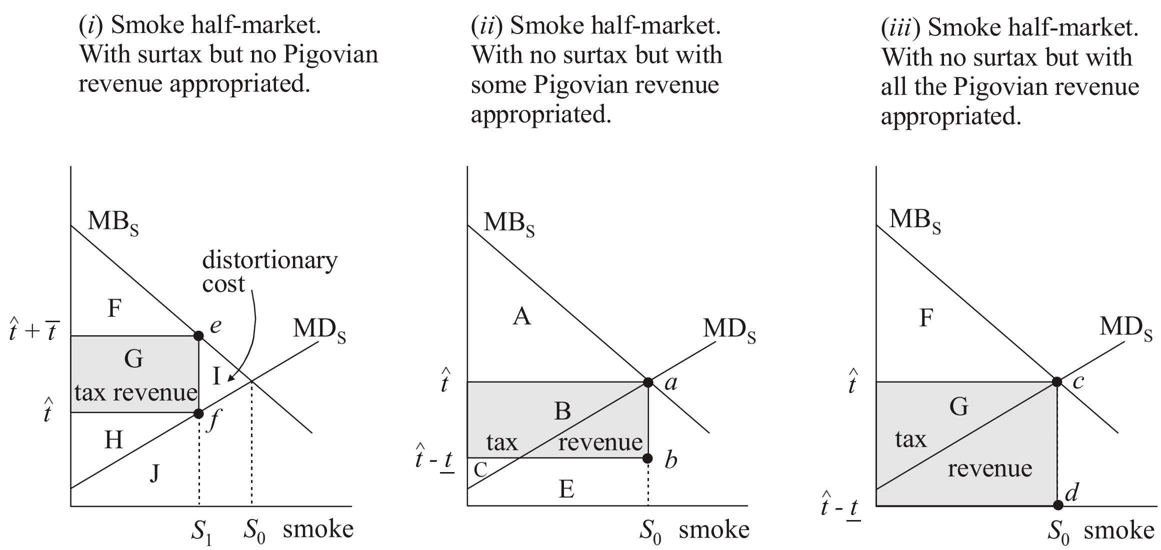
[11] Of course, if someone dies from an airborne or waterborne carcinogen, it will not be possible to make the person "whole" by compensation. The cost-benefit idea here is to value the risks *ex ante*, before the dice are rolled. This was the idea used in Chapter 11, where the revealed preference approach led to an estimated value of a statistical life in the range of $2 – 3 million.

compensation. We'll look first at the distributional effects from the government appropriating the Pigovian revenue.

17.4.2: The Government Appropriates Some or All of the Pigovian Revenue

We consider next how the government can avoid the administrative problem of estimating the individual marginal damages, by keeping the Pigovian revenue rather than using it for Pigovian compensation. We do this in steps. Figure 17.8(*i*) is our starting point. It is the case where there is an environmental surtax $\bar{t}$ but all the Pigovian revenue is used to compensate the recipients of the environmental harm (this is the same diagram as panel (*ii*) of Figure 17.6). Next, in panel (*ii*) of Figure 17.8 the government keeps part of the Pigovian revenue and eliminates the surtax $\bar{t}$. In the diagram the government appropriates the Pigovian revenue at the rate of $\underline{t}$ per unit of smoke and compensates the harm recipients at a rate of $(\hat{t} - \underline{t})$ per unit of smoke. The appropriated Pigovian revenue $\underline{t}S$ (or area B) is a source of tax revenue just as much as G is a source of tax revenue in panel (*i*).

Figure 17.8
Asymmetric Environmental Surtax



There is something unusual about this revenue source B. I have drawn the first two panels of Figure 17.8 so $\underline{t}$ is the same amount as $\bar{t}$. If the equivalence property for ordinary taxes also applied to the environmental taxes $\underline{t}$ and $\bar{t}$, the two panels would look the same. But panels (*i*) and (*ii*) differ. We checked panel (*i*) before, so all we need is to see what is happening in panel (*ii*). Because the producers' after-tax price of smoke emissions is $\hat{t}$ (they pay no surtax), they equalize their marginal benefits with their after-tax price of smoke at *a* in panel (*ii*) and emit S_0 smoke. Because smoke is an externality, the smoke recipients live with this amount. Their marginal damage is at *a* for smoke emission S_0. The recipients only receive a per unit compensation of $(\hat{t} - \underline{t})$ and they are not fully compensated for their harm, but recipients cannot individually change the rate of compensation (they might be able to if they acted politically).

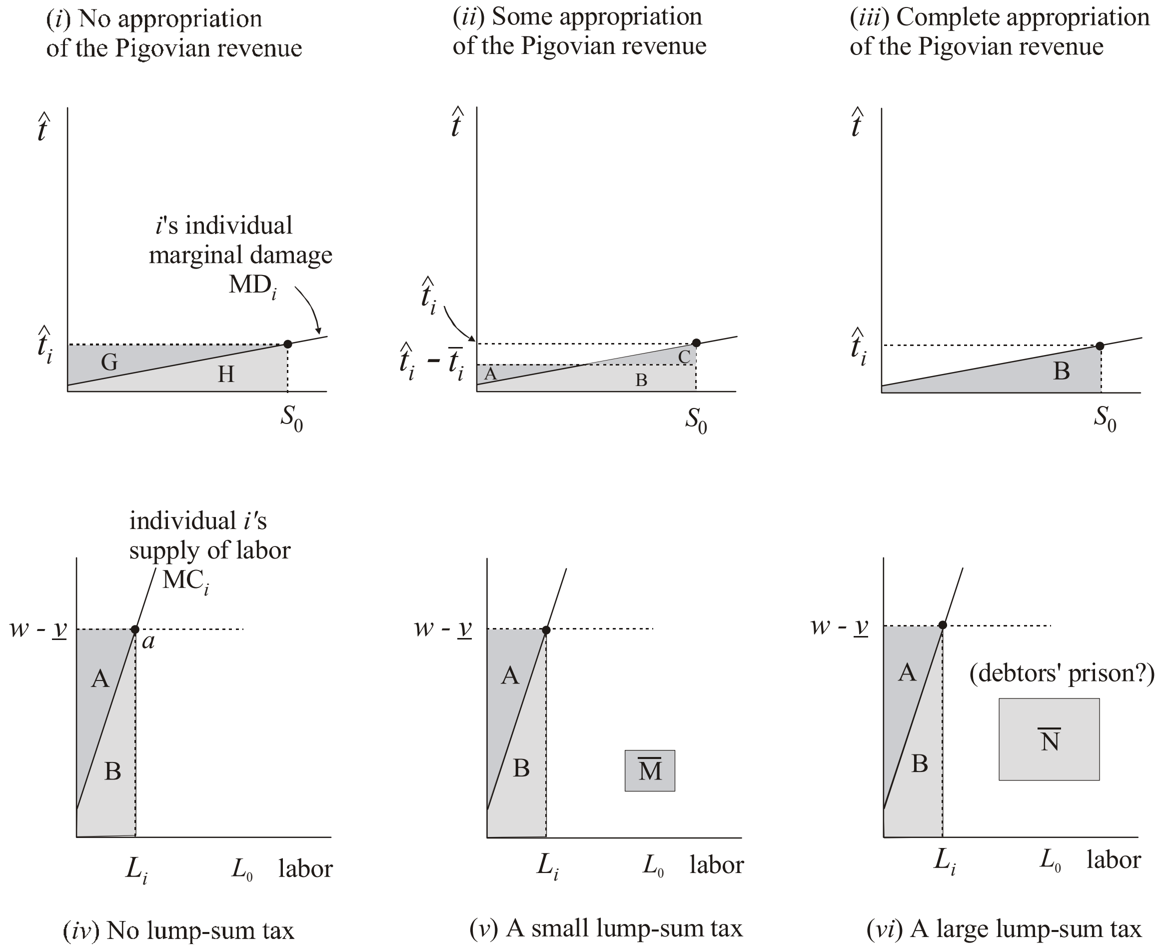
Comparing panels (*i*) and (*ii*), there is no distortionary cost in panel (*ii*) and the tax revenue B is larger than the tax revenue G in panel (*i*). The other areas differ as well. We conclude that the equivalence property for ordinary taxes does not apply to environmental taxes (the reason for this difference is the externality).

In panel (*iii*) the government appropriates all the Pigovian revenue. In other words $\underline{t} = \hat{t}$. In this case the rate of compensation to the harm recipients is $\hat{t} - \hat{t} = 0$. This means that the recipients get no compensation and all the Pigovian revenue is transferred into the government treasury to finance publicly produced goods and services or reduce other taxes. When this source of revenue equals the government's revenue need, the government can replace all other tax revenues with the Pigovian and finance the revenue need without any distortionary cost in the tax system. This is Sandmo's example. (Later we'll consider the more likely case when the Pigovian revenue is not enough by itself to finance the government's revenue need.)

Appropriating all the Pigovian revenue solves the administrative problem. There is no need to estimate the individual marginal damages when all the Pigovian revenue is appropriated. All that is needed is an estimate of the sum of the marginal damages. As mentioned before such estimates (with uncertainties) are routinely made in environmental damage assessments (they have their errors and sometimes estimate average damage rather than marginal damage, but they are useable and have been used in second-best analysis). Remember also that the case when the Pigovian revenue is appropriated (but not the surtax) is when economists have found second-best environmental taxes are often 35% less than their Pigovian levels and the recommended second-best levels of environmental harm are often substantially higher than the corrective Pigovian levels.

Figure 17.9 shows how adverse distributional consequences arise when the Pigovian revenue is appropriated.

Figure 17.9
Distributional Consequences from the Government
Appropriating the Pigovian Revenue



The three top panels of the diagram are for the smoke half-market. Panel (*i*) above is the same as panel (*iv*) of Figure 17.2 and shows individual *i*'s Pigovian compensation G + H more than covers her total environmental damage H when smoke emissions are S_0. But in panel (*ii*), when the government appropriates part of the Pigovian compensation into the general treasury, the remaining part A + B, may or may not cover *i*'s environmental damage B + C. In panel (*iii*) the government appropriates all the Pigovian revenue into the general treasury, paying none of the Pigovian revenue as compensation. In this case *i* has a net loss B from the environmental harm.

The three lower panels are for the labor market. We use them to compare the government's appropriation of the Pigovian revenue to a lump-sum tax. Panel (*iv*) is the same as panel (*iii*) of Figure 17.2, except it includes $\underline{v}$, a tax collected from the laborers. With the tax the wage adjusts and each laborer equalizes her marginal cost of labor with the after-tax wage rate $(w - \underline{v})$ at *a*. Labor compensation A + B covers the cost of labor. In panel (*v*) of Figure 17.9, there is in addition to the labor tax $\underline{v}$ a lump-sum tax $\overline{\mathrm{M}}$. If *i*'s labor compensation A + B is *i*'s only source of income, it is not clear that this income (A + B) will cover *i*'s cost of labor and the lump-sum tax (B + $\overline{\mathrm{M}}$). In panel (*vi*) of Figure 17.9 the lump-sum tax is most of *i*'s labor compensation, and it looks like *i* may be off to debtors prison (or our modern equivalent of it).

Figure 17.9 illustrates the idea that appropriating the Pigovian revenue and lump-sum taxes have similarities in their distributional effects. Those who bear the largest burdens when environmental harms are not compensated or partially controlled are the old, the young, the ones with compromised immune systems, people with limited incomes and fewer defensive strategies like moving away from the environmental harms, etc. Those who bear the largest burdens when lump-sum taxes are imposed are the poor.

The idea of a lump-sum tax is a tax that a person cannot avoid by modifying his behavior. The government's appropriation $\underline{t}S$ is a source of revenue (see for example Figure 17.8). Recall that $\hat{t}_i$ is defined, in principle, as what *i*'s marginal damage would be if *i* took his efficient defensive strategy (and not by what he actually does). With this definition, the government's appropriation of some or all the Pigovian compensation is a lump-sum source of revenue. Individual *i* can't avoid the government's appropriation of part or all the Pigovian revenue. By the same idea, the part of the Pigovian revenue that the government uses to compensate the harm recipients is a lump-sum compensation to the recipients. (An individual recipient can't affect this either, by his own action, except politically, or in rare cases by going to court.)

Appropriation of the Pigovian revenue is odd in another way. The producers who pay the total environmental tax $(\hat{t} + \bar{t})$ care about the whole tax. They alter their behavior to avoid it, and this is most of the reason for imposing the environmental tax in the first place. (The reason for imposing the Pigovian part is corrective and the reason for imposing the surtax is to obtain revenue.) But whatever fraction of the Pigovian revenue the government chooses to distribute to the harm recipients does not affect the producers' profits. For this reason producers' have no incentive to alter their behavior as a result of the government's choice of $\underline{t}$, the rate of transfer of the Pigovian revenue into the general treasury.

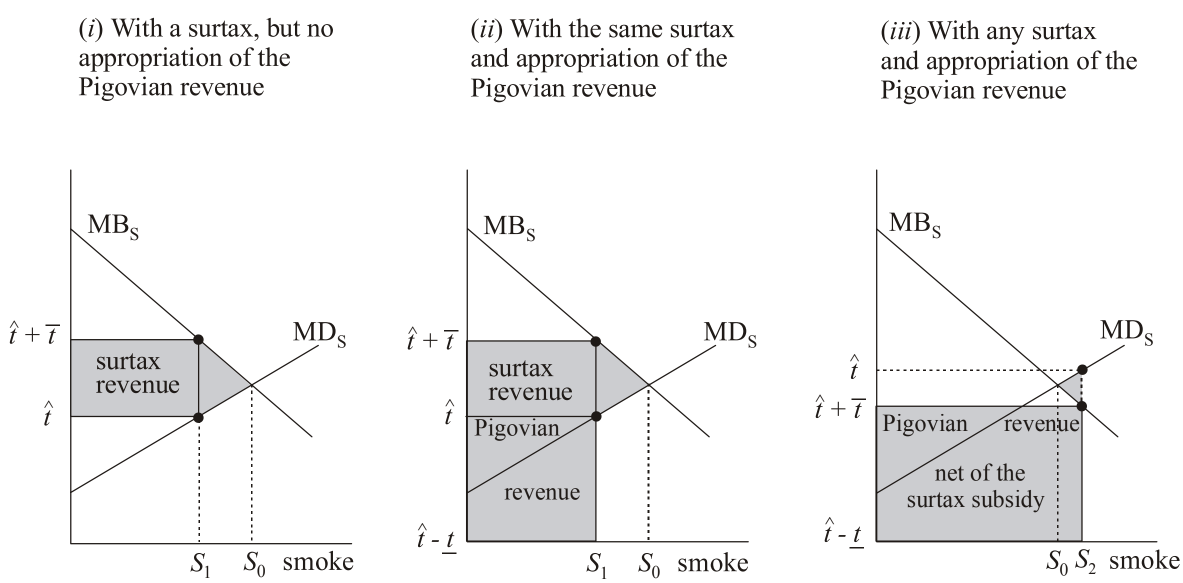
What I have just said is not quite precise. By choosing different rates of transfer of the Pigovian revenue, the harm recipients will be richer and poorer, and these differences will affect the economy, including the producers' profits. But this is also true for lump-sum taxes. Higher or lower lump-sum taxes will make individuals richer or poorer and affect the whole economy. This is another similarity between the government's appropriation of the Pigovian revenue and ordinary lump-sum taxes.

The biggest similarity is that appropriating the Pigovian revenue is a non-distortionary source of revenue (recall Figure 17.8), but with adverse distributional consequences (similarly lump-sum taxes are non-distortionary with adverse distributional consequences). Both sources of government revenue—appropriating the Pigovian revenue and lump-sum taxes—are strong on efficiency and weak on equity (distributional fairness).

17.4.3: A Look without the Tax Interaction Effect

Sometimes you can learn about the effect of something by seeing what happens when the effect is not there. Let's see what happens to the Pigovian revenue when there is no tax interaction effect. We can do this by studying what happens when the environmental tax is the only tax. When there are no other taxes there are no tax interaction effects. Figure 17.10 shows three cases.

Figure 17.10
The Smoke Half-Market with no Tax Interaction Effects



Panel (*i*) is basically the same as panel (*i*) of Figure 17.8, but this time I've identified the tax revenue as coming from the surtax and shaded the distortionary cost. This case arises when the environmental tax is constrained to have its Pigovian revenue used to compensate the harm recipients. The surtax is unconstrained. This is a case of symmetry where the surtax behaves like an ordinary tax. When there are no other taxes, as we are assuming for the moment, the surtax must be positive (otherwise it wouldn't raise revenue but would still have a distortionary cost).

Roughly speaking, the second-best maximization is solved by finding the environmental tax that maximizes the area of the revenue rectangle minus the area of the distortionary cost triangle (for the constraints on the environmental tax).[12] I have drawn panel (*i*) to show approximately this maximum of revenue minus distortionary cost and $\bar{t}$ is approximately the second-best surtax.

In panel (*ii*) the constraints change. We constrain the surtax to be the same amount as it was in panel (*i*), but we relax the constraint requiring the Pigovian revenue be used to compensate the harm recipients. Without the constraint the government can appropriate as much of the Pigovian revenue it wants. With this change in constraints, second-best maximization (as defined in Box 3) recommends appropriating the full Pigovian revenue. Why not? It's a source of distortion free revenue. The rectangle grows but the triangle remains the same.

In panel (*iii*) the constraints change again. We unconstrain the surtax and we allow the use of the Pigovian revenue unconstrained, like it was unconstrained in panel (*ii*). Second-best analysis recommends the government keep its appropriation of the Pigovian revenue. But there is more. In panel (*iii*) the area of the revenue rectangle minus the area of the distortionary triangle is larger than in panel (*ii*). And in panel (*iii*) the total environmental tax is less than its Pigovian level. Here's the idea. When the Pigovian revenue is appropriated, and there is no constraint on the surtax (or the whole environmental tax), second-best analysis often recommends subsidizing the price of the environmental harm (by setting the environmental tax less than its corrective Pigovian level. This has the effect of increasing the amount of smoke above its corrective Pigovian level, in the process augmenting the Pigovian revenue (remember the Pigovian revenue is the product of the sum of the marginal damages times the amount of the amount of smoke, and both increase with a decreased environmental tax and increased amount of smoke). By subsidizing the environmental harm, a non-distortionary source of revenue is augmented (the Pigovian revenue). In effect, by setting the environmental tax lower than its corrective Pigovian level, second-best analysis is shifting the tax system toward lump-sum sources of revenue. This shift doesn't go on forever. Eventually, as the environmental tax is decreased, the net appropriated environmental revenue declines. In the extreme, if the environmental tax were set at zero, there would be no environmental tax revenue at all.

Now we have a quite different interpretation of why second-best analysis sometimes recommends setting environmental taxes lower than their corrective levels and

[12] By roughly, I mean under some simplifying conditions that we won't explore.

the amounts of environmental harm greater than their corrective levels. The earlier explanation depended on the distortionary nature of the tax interaction effect. The new explanation depends on the non-distortionary nature of appropriating and augmenting the Pigovian revenue.

We are almost done with the economic analysis. But we need to look a little further at what happens when there are multiple taxes.

17.4.4: Multiple Taxes and Tax Opportunities

A simple idea helps us extend the previous analysis to the more realistic situation where there are many taxes and tax interaction effects. The humorist Will Rogers once said that he never met a person he didn't like. Something similar happens in second-best analysis. Second-best analysis never met a new tax opportunity it disliked.

Here's the idea. When you do the second-best problem, and maximize the NSB subject to constraints, if you relax a constraint on taxes you can never do worse and you can often do better. Since the constraint is relaxed, you can always get the same NSB you had before. But with the new opportunities from the relaxation, you can often find a new, higher NSB.

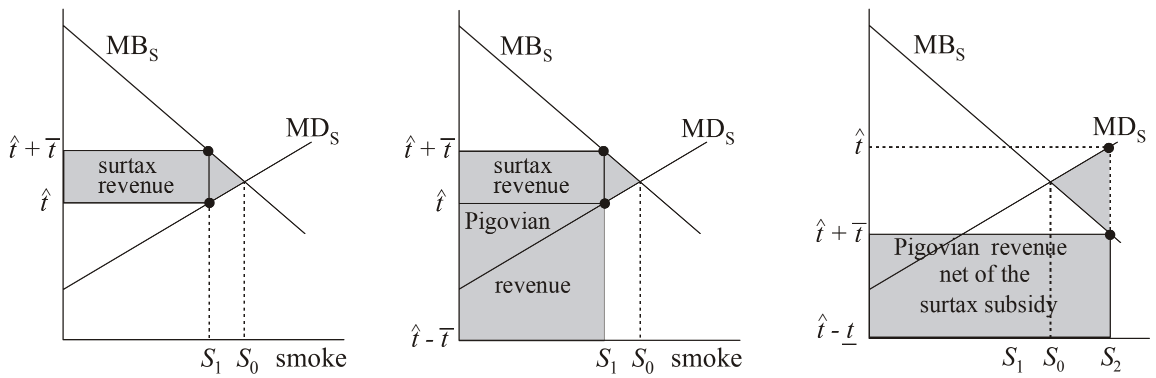
Now let's apply this idea to Figure 17.10, but with one new interpretation. Before the diagram was drawn with the interpretation that the environmental tax was the only tax. Since we didn't have to deal with tax interaction effects, we could do the second-best maximization by looking only at the smoke half-market and the areas of the rectangle and the triangle for this market had a direct interpretation in the second-best analysis. Now we will give up the direct comparison of areas and use Will Rogers' idea instead.

Figure 17.11
Balancing Efficiency and Equity

(*i*) Constraint of Pigovian compensation; no constraint on the surtax.

(*ii*) Distribution of the Pigovian revenue unconstrained; surtax constrained to level in panel (*i*).

(*iii*) No constraints on the distribution of the Pigovian revenue or on the surtax.



Spreading
Lowest NSB
Least adverse distributional consequences
Administratively difficult (or impossible)

Spreading & Appropriation
Most of the NSB
More adverse distributional consequences
Administratively feasible

Spreading, Appropriation & Augmentation
Highest NSB
Most severe adverse distributional consequences
Administratively feasible

Figure 17.11 is the same as Figure 17.10, with a few adjustments. With multiple taxes, panel (*i*) is still the symmetry case (the Pigovian revenue is used as compensation). So, we expect the surtax to be typically positive like ordinary taxes, as shown in panel (*i*) of Figure 17.11. But with many taxes, it is possible to **spread** the burden of distortionary costs over many taxes, typically with lower taxes for each tax. So in this symmetry case I have drawn the surtax, which is behaving like an ordinary tax in panel (*i*), a little smaller than the surtax in Figure 17.10(*i*), when it was the only tax.

The symmetry case in panel (*i*) has the constraint that $\underline{t}=0$ (none of the Pigovian revenue is appropriated), but there is no constraint on the surtax. In moving from panel (*i*) to (*ii*) we constrain the surtax to be what it was in panel (*i*) but relax the constraint on $\underline{t}$ (any amount of the Pigovian revenue can be appropriated). The old tax opportunity is still available (namely the same surtax and no government appropriation of the Pigovian revenue and there are no new constraints on the other taxes). So in the second-best maximization it is possible to get the same NSB as before. But with the new opportunity to **appropriate** the Pigovian revenue, second-best maximization may lead to a higher NSB. Qinghua Zhang and I were able to show this always happens in our model of second-best maximization. Our interpretation is that this happens because appropriating the Pigovian revenue is a distortion-free source of revenue for the government (but remember that we are in an area of emerging research and there is not a settled consensus on this interpretation).

In moving from panel (*ii*) to (*iii*), we relax another constraint in panel (*ii*), the constraint on the surtax. The old opportunity of panel (*ii*) is still available so the new maximum NSB will be at least as high as the old one. Typically with the new opportunity it will be higher. Moreover, in several studies the surtax maximizing the NSB is negative (so the total environmental tax is less than its Pigovian level, as shown in the diagram). The difference between panel (*iii*) of Figure 17.11 and the corresponding panel (*iii*) of Figure 17.10 is that I have drawn the second best surtax a little more negative in Figure 17.11. It appears[13] that with multiple taxes when the Pigovian revenue is appropriated, the tax interaction effect adds to the benefits of **augmentation**, leading to a more negative surtax. In effect the negative surtax subsidizes the environmental harm to achieve a larger Pigovian revenue. The subsidy creates its own distortionary cost, as shown in panel (*iii*) but this cost is offset by the gain in distortionary-free Pigovian revenue.

17.5: The Policy Problem

Figure 17.11 illustrates the policy problem. In panel (*i*) there are the least adverse distributional consequences, but also the lowest NSB. In panel (*iii*) there are the most adverse distributional consequences, but the highest NSB. Panel (*ii*) has a middle level of adverse distributional consequences and NSB. In the second-best analysis, the three choices result from different constraints on taxes.

The policy problem is familiar—to balance an equity goal (limiting adverse distributional consequences) with an efficiency goal (maximizing NSB). In terms of the second-best analysis the policy problem boils down to deciding what constraints should be placed on the tax opportunities. In second-best analysis constraints are routinely placed against the use of lump-sum taxes and often put on the total government revenue (revenue neutrality). What constraints, if any should be placed on the tax opportunities of environmental taxes?

If policy makers conclude that appropriating the Pigovian revenue is the same as a lump-sum source of revenue, or has similar adverse distributional consequences, consistency suggests that they decide against appropriating the Pigovian revenue, and instead use the revenue for Pigovian compensation. But if policy makers decide that it is hard or impossible to implement Pigovian compensation, they may forgo the option of

[13] I say "appears" because there are still few studies on how tax interaction effects relate to relaxations of constrains on the surtax.

panel (*i*) and choose between panels (*ii*) and (*iii*), in other words between a constrained level of the surtax and an unconstrained level of the surtax. Or policy makers could choose constraints leading to something between panels (*ii*) and (*iii*).

There are two ways of limiting the adverse distributional consequences of environmental harms. One is to limit the harms by tighter regulation. The other is to compensate the most injured. Panel (*ii*) limits the distributional consequences by limiting the harm, compared with its corrective Pigovian level S_0, while it forgoes Pigovian compensation.

The difference between panels (*ii*) and (*iii*) comes from relaxing the constraint on the surtax and obtaining the opportunity to augment the Pigovian revenue and the government's net environmental revenue, the shaded rectangle in panel (*iii*). Compared with panel (*ii*), panel (*iii*) has higher NSB but more severe distributional consequences.

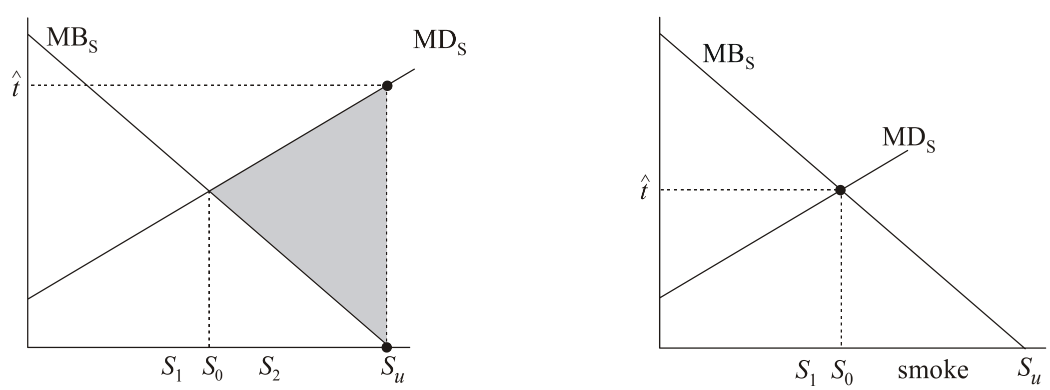
How the government should balance the efficiency and equity goals is an unresolved and a hotly debated policy question. Second-best analysis is just a way of framing the policy debate, a way that economists are increasingly using. But the "appropriate" choice of constraints is up for grabs. You are welcome to join the debate on constraints and the balance between efficiency and equity.

The policy choices in Figure 17.11 are just a few of the many possibilities. Here are a few more.

Figure 17.12
More on Efficiency and Equity

(*i*) No regulation

(*ii*) Corrective command and control.



Adverse distributional consequences more severe and NSB lower than in Figure 17.11(*iii*)

Adverse distributional consequences more severe and NSB lower than in Figure 17.11(*ii*)

Figure 17.12(*i*) is no regulation. This corresponds to the second best problem where the environmental tax is constrained to zero. With a zero price of the environmental harm the producers have an incentive to emit smoke to where their marginal benefits are zero, for example at S_u in Figure 17.12(*i*), or in Figure 17.1(*ii*). There is no Pigovian compensation paid to the harm recipients. It is as though the government appropriates the Pigovian revenue and uses it to finance the subsidy to the producers. In this interpretation, the producers also pay no net environmental tax, the government has no net revenue from the tax, and the harm recipients have no compensation.

The adverse distributional consequences in Figure 17.12(*i*) are more severe than in Figure 17.11(*iii*), because the uncompensated harm is greater, and the NSB is typically less, because the environmental tax is constrained. (But sometimes the marginal damages of the environmental harm are low, and the administrative costs of regulation are high, so that regulation is unwarranted.)

Figure 17.12(*ii*) shows the case of corrective command-and-control. It is similar Figure 17.11(*i*), with two adjustments. Start with Figure 17.11(*i*) and set the surtax equal to zero. Then there would be no surtax revenue (and no direct distortionary cost of the shaded triangle). Next, take the Pigovian revenue and instead of using it as compensation to the harm recipients return it to the producers in a lump-sum form. The producers end up emitting smoke at the corrective level S_0 (because they pay the per unit Pigovian tax) but they "are made whole" because they get the Pigovian revenue back lump sum. In this case the NSB is likely to be less than in Figure 17.11(*i*), because the surtax is constrained to zero, and the adverse distributional consequences are more severe, because there is no Pigovian compensation and the level of the harm is higher, at the corrected level of S_0 instead of the lower level of S_1. These efficiency and equity considerations need to be balanced in turn with administrative and political feasibility.

Summary and Conclusion

Environmental protection is simpler in a world without ordinary taxes. Environmental taxes, set at their corrective Pigovian levels in principle achieve efficiency and their Pigovian compensation limits adverse distributional consequences. Command-and-control regulation and marketable permits can be analyzed by their relatedness to environmental taxes.

When economists began to think about the effects of ordinary taxes and the need to finance public goods, they had the hope of a double dividend. But then when economists identified tax interaction effects this hope diminished. Yet we can see that starting from a point of no regulation in Figure 17.12(*i*) and moving to the unconstrained second-best environmental tax of Figure 17.11(*iii*) there is still a form of the double dividend. In the move, the NSB increases and the environmental harm decreases (and with the increase in the NSB) the total distortionary cost of the tax system decreases, and with the environmental harm reduced the adverse distributional effects are reduced as well. But this double dividend is limited. In moving from Figure 17.11(*iii*) to (*ii*) the harm continues to decrease but the NSB decreases too (with a gain in equity and loss in efficiency).

Considering that an explicit policy goal is to “protect the most vulnerable with an adequate margin of safety” the second move may still be worthwhile. In a similar but somewhat weaker way the move from the partially corrected environmental harm in Figure 17.11(*iii*) to the fully corrected command-and-control of Figure 17.12(*ii*) may also be worthwhile. Such a move, while not achieving Pigovian compensation, still achieves part of the equity goal by limiting the harm further than in Figure 17.11(*iii*).

Ordinary taxes have but one opportunity to raise revenue—by tax spreading. Environmental taxes have three—by tax spreading, appropriating the Pigovian revenue, and by augmenting it. In this sense, environmental taxes are not unusually distortionary but unusually non-distortionary. The revenue raising opportunities and the distributional consequences may become especially important if and when such large scale actions, such as control of greenhouse gases, are undertaken. Even limiting environmental taxes to their tax spreading and appropriating opportunities may make environmental taxes more attractive than ordinary taxes, with their single opportunity of tax spreading.

But a final caution – this is an emerging field of inquiry – with future surprises and reformulations, but almost certainly with the perennial dilemma of how to balance efficiency and equity goals.

Concepts and Definitions

corrective
“half-market”
producers’ equalization
laborers’ equalization
market clearing
Pigovian revenue
distortionary cost
equivalence property of ordinary taxes
tax interaction effect
second best problem
first-best efficient
tax spreading
appropriating the Pigovian revenue
augmenting the Pigovian revenue