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EMPLOYMENT, ENVIRONMENTAL TAXES, AND INCOME TAXES

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I. INTRODUCTION

Governments have revenue requirements, which they meet by taxing various goods and activities. Revenue-raising taxes are generally distortionary because, by altering relative prices, they change individual decisions compared to the no-tax situation. This change in behavior involves a cost to society that outweighs the revenue raised (often called the dead-weight loss). For example, a tax on wages drives a wedge between the wage that producers pay and the wage that workers receive. The divergence between the marginal return to work and the value of the product leads to a work effort that is below the amount that maximizes social welfare.

Taxes can also be used as a method of correcting for externalities in the economy. An externality exists when activities impose costs that are ignored in individual decisions. A good example is environmental externalities, such as pollution. For example, when I take a trip in my car, I ignore the fact that you breathe my exhaust fumes. Environmental taxes, therefore, correct distortions that result from nonexistent or incorrect market prices.

Because environmental taxes both raise revenue and correct distortions, it has been suggested that there could be a “double dividend” from the revenue-neutral introduction of an environmental tax and the reduction of an existing distortionary tax. In recent years, policy makers have appealed to this notion in the context of taxing “bads” (such as pollution) and reducing taxes on “goods” (such as labor or payroll taxes). One particular second dividend from a revenue-neutral shift from labor to environmental taxes is a rise in employment.

Early analysis of environmental taxes (Pigou’s, for example) tended to ignore the possibilities for pending the revenue raised and assume it was returned to the economy in a welfare-neutral way. A tax that raises $1 of revenue is used in a way that has equivalent value ($1): It is either returned as a lump sum, which allows individuals to make consumption decision, or the government spends it. Environmental taxation yields a single dividend of correcting the externality (i.e., an improved environment). The term “double-dividend” has been coined from the notion that the revenue could be recycled in a way that produces additional benefits, or a second dividend. The literature distinguishes between a weak and a strong double dividend, depending on the form of additional benefit.

To see the difference, suppose the government receives new information about an environmental bad. It is then able to adjust the tax structure to tax the bad. Compared to the situation where the government returns the revenue as a lump-sum transfer, recycling the revenues to reduce another tax generates an additional benefit. This has sometimes been referred to in the literature as the *weak double dividend.* This result relies on a situation in which the existing tax structure is suboptimal, given the new environmental information. New information on an environmental bad can therefore lead to an optimal change in the structure of taxation that increases "green" taxes and reduces existing distortionary taxes including reductions in the taxation of labor.

A much stronger claim is often made for a double dividend. The claim is that introducing an environmental tax and reducing existing taxes not only improves the environment but will also *reduce* the dead-weight costs associated with the tax system. Introducing the environmental tax will generate a welfare gain even if we ignore the improvement in the environment. Although the claim sounds appealing, it is not, in fact, at all obvious. It suggests that even with no new information on an environmental bad, there is a gain from switching from an existing distortionary tax to a green tax, which could occur only if the current tax structure is suboptimal. The intuition is as follows. Consider that environmental taxes have two of the same attributes as standard, or ordinary taxes. They raise revenue and alter consumer behavior by changing prices. This change in behavior involves a distortionary cost in the same way as other taxes—if there is a tax on gasoline, then driving becomes more expensive, reducing drivers' welfare by more than the revenue raised. The extra attribute of an environmental tax is that by altering behavior, it leads to an improvement in the environment. With an environmental tax, the improvement in the environment and the revenue raised outweigh the loss to consumers of increased prices from the tax. With an ordinary tax, by assumption, there are no external gains to offset the welfare loss of higher prices (hence the dead-weight cost associated with distortionary taxes).

The strong double-dividend argument therefore hinges on the nonenvironmental aspect of welfare. The argument requires that the environmental tax raises revenue in a less distortionary way than the tax it replaces, so that there is a welfare gain associated with the tax swap *even if we ignore the environmental improvement.* But there is no reason to suppose that the environmental tax necessarily raises revenue more efficiently than the tax it replaces. Indeed, if the tax system was initially designed for revenue-raising efficiency, an efficiency-improving tax swap would not be possible—introducing the environmental tax and reducing an existing tax would increase the dead-weight loss of revenue collection. This is not to say, of course, that the environmental tax should not be introduced, since there are environmental gains to offset the associated costs.

The rest of this paper is organized as follows. Chapter 2 explores the effects of introducing an environmental tax in a simple model with revenue-raising taxes. It then goes on to discuss the setting of optimal taxes when there are both revenue-raising and environmental concerns, and how this can be affected by the inclusion of distributional considerations. Chapter 3 reviews a selection of the double-dividend literature, and considers features of the basic models that suggest an enhanced likelihood of a double dividend from an environmental tax shift. Chapter 4 presents conclusions based on the theoretical literature. Chapter 5 summarizes the limited empirical work on the double dividend, as well as alternative literature that sheds light on the validity of the hypothesis. Because no work has directly evaluated the labor market effects of an environmental tax shift, it is difficult to make firm conclusions about the empirical validity of the double-dividend hypothesis. Chapter 6 presents overall conclusions.

II. REVENUE RAISING AND ENVIRONMENTAL TAXES

RAMSEY AND PIGOUVIAN TAXATION

The double-dividend issue is basically a (second-best) optimal tax question. Optimal tax theory provides conditions on how taxes should be set to meet the government's revenue requirement while maximizing social welfare. This can be quite general and include, for example, distributional concerns.[1] The starting point for this literature is usually associated with Frank Ramsey, who asked if lump-sum taxes (which are nondistortionary) cannot be used, how other taxes should be set to meet the government's revenue requirement in the least distortionary way. On the externalities side, the idea of using corrective taxation originated with Pigou. Both Ramsey's and Pigou's initial analyses were undertaken in otherwise perfect economies. Ramsey calculated optimal revenue-raising taxes in an economy with no other distortions such as externalities, and Pigou calculated optimal environmental taxes in a world with no other existing distortions such as revenue-raising taxes. There is no reason why the two cannot be combined into a more general model. Overall optimal taxes are calculated by maximizing welfare, subject to the revenue requirements, where welfare now includes the effects of externalities. Indeed, although the double-dividend debate is relatively new, optimal taxation with externalities was first explored by Sandmo in 1975. We consider first a simple example to illustrate the arguments outlined in the introduction.

1. In this paper, "efficient" tax collection can mean meeting revenue requirements in the least distortionary way given distributional concerns that, of course, could give a different tax setting perscription to if those distributional aims were absent. Distributional considerations are absent in this particular section, since we will be considering identical individuals

INTRODUCING AN ENVIRONMENTAL TAX

Suppose we have a linear production function with labor, L, (of fixed productivity) as the only input, which can produce two consumption goods at equivalent unit cost, a clean good C and a dirty good D. The dirty good is so called because it is the consumption of this good that generates the environmental externality. Suppose that the government is unaware of this externality at present, so there is no environmental taxation. Producer prices can be normalized to unity. A starting assumption in this analysis is that consumers are identical; and their utility is weakly separable between the level of the externality E, (equivalently, the negative of environmental quality), government expenditure G, and the rest of utility (consumption and leisure). The separability assumption simply means that the level of the externality and of government expenditure do not affect the leisure/consumption choice. Utility is a negative function of E, and $E = f(D)$, where $f' > 0$. We can choose $f' = 1$ for simplicity. The government can raise revenue by taxing C, D, and L. Because wages are the only source of income in this model, a wage tax is equivalent to a uniform tax on both goods. This means that one consumer price can be normalized to unity (i.e., be untaxed). Let's choose C, so $G = t_L L + t_D D$. Optimal revenue-raising taxes, or Ramsey taxes, on labor and the dirty good are calculated by optimizing consumer welfare subject to the government's revenue requirement.

Now suppose that the government receives news that D generates an externality. In an otherwise perfect economy, the first-best (Pigouvian) tax to correct this externality (call it $t_D{}^P$) would be equal to marginal environmental damage (or equivalently, the marginal willingness of the consumer to pay to avoid the externality):

$$t_D{}^P = (-V_E \,/\, V_M)$$

where V denotes the consumer's indirect utility function, V_E is the marginal utility of the externality, and V_M is the marginal private utility of income.

Suppose that the government was lucky enough to find that getting rid of other taxes and using the Pigouvian tax alone raises enough revenue to meet (or exceed) G. Then only Pigouvian taxation on D is needed, and any revenue exceeding G can be given back as a lump sum. Suppose now that the government has a zero-revenue requirement. In this case, when it receives news about the externality, the government should set the Pigouvian tax on D and redistribute all the revenue raised. There is a greater welfare gain in the first situation compared to the second, since the final outcome is the same[2], but there is an initial dead-weight loss from distortionary taxation in the first situation and not in the second. In this sense, there is a double dividend from using the environmental tax and reducing other taxes, and this is precisely what is sometimes referred to as the "weak" double dividend. Early analysis of environmental taxation often ignored possible uses of the tax revenue, assuming it is redistributed lump sum (thus having no distortionary impact). But governments *do* have revenue requirements, so it is important to consider that externality-correcting taxes raise revenue since they can be used to replace existing taxes. Revenue recycling raises the prospects for welfare gains.

A much stronger claim, however, is that introducing an environmental tax and reducing existing distortionary taxes will generate an environmental gain *and* an improvement in the efficiency of tax collection. That is, such a tax reform will raise welfare *even if* we ignore the environmental aspect of welfare. This outcome cannot possibly happen in this example, however, except by assuming that the government had initially chosen taxes as the optimal way to raise revenue. The environmental tax reform cannot improve the efficiency of tax collection.

It is important to recognize that environmental taxes and ordinary taxes have two of the same attributes: They raise revenue, and they alter consumer behavior by changing prices. If environmental gains are ignored, then an environmental tax will be associated with a dead-weight cost just like any other tax. If taxes were initially set optimally from a revenue-raising point of view, then introducing the environmental tax and reducing an existing tax must increase the dead-weight loss of revenue collection. But there is a weak double dividend in that it is better than ignoring what can be done with the revenue and simply redistributing it in an efficiency-neutral (lump-sum) fashion, even though using the revenue to lower an existing tax cannot improve the efficiency of revenue collection. This is intuitively easy to understand—raising revenue using a distortionary tax and redistributing it lump sum is less efficient than having no taxation at all.

The only way for a strong double dividend to arise is if initial revenue-raising taxes had not been set optimally. However, any improvement in the efficiency of tax collection, when only the environmental tax is used, would be unrelated to the fact that it is an environmental tax. The government should have reformed the tax system even if there had not been new information about the existence of the environmental externality. Obviously, the reform might not be exactly the same, since there would be no need to tax the dirty good (D) for environmental purposes.

2. Assuming an equal valuation of private and public spending.

OPTIMAL TAXES

Thus far we have explored the case where Ramsey taxes can be completely replaced by Pigouvian taxes, since the revenue from the Pigouvian tax meets or exceeds the government's requirements. This result is useful because it is a simple way of explaining the ideas behind the double-dividend argument, but it is highly unlikely that the government could raise all required tax revenue from environmental taxes alone. Although the government cannot completely switch to Pigouvian taxes in this case, logic identical to that used in the simple example applies. If the tax system was initially raising revenue optimally, then increasing the tax on the dirty good and reducing other taxes cannot improve the efficiency of tax collection. The important point to take from this discussion is that the prospect of a double dividend is almost eliminated if the government optimally raises its revenue.

In practice, tax revenue is not raised optimally. Our interest here is to characterize optimal taxes when environmental concerns are introduced in the presence of existing distortionary taxes. Will the presence of other distortionary taxes alter the environmental tax compared to the Pigouvian tax? Will the environmental tax be greater or smaller than the marginal environmental damage? Sandmo provided the answer to these questions.

The tax on labor or on the clean good has the same structure as the "Ramsey" formula for optimal taxation in the absence of externalities. Thus, only the efficiency of the tax system determines these taxes and not environmental concerns. The tax on the dirty commodity consists of a Ramsey component (call it $t_D{}^R$) plus an environmental component (call it $t_D{}^E$). This general result is known as the *Sandmo additivity property*. The formula for $t_D{}^E$ is given as:

$$t_D{}^E = (1 \setminus \Gamma)\ t_D{}^P$$

where Γ is the marginal cost of public funds (MCPF). The MCPF reflects the social cost of raising an additional dollar of revenue. The MCPF is greater than one if financing additional public spending erodes the tax base of the existing Ramsey taxes. We usually think that the MCPF will be greater than one—increasing the tax on a good tends to reduce consumption of the good (but note that we need to consider cross-price effects). If the MCPF is greater than one, raising an extra dollar of revenue has a social cost that is greater than one dollar. When there are environmental objectives and revenue objectives, the optimal environmental part of the tax on *D* measures the social costs of pollution in terms of public (not private) income. It equates the costs of pollution to the social benefit of the public goods that can be financed by the additional revenue. If an extra dollar of public revenue has a social cost that is greater than one dollar, then the second-best optimal environmental part of the tax on D is less than the marginal environmental damage it causes.

The basic point is that when there are preexisting distortions in the economy (such as taxes), the welfare effects of an externality-correcting tax include its indirect effects on those distorted markets. Here, the tax on D adds to the distortion in the labor market. It reduces the real wage, which reduces labor supply, which thus erodes the tax base. This effect is not restricted to the existence of distortionary taxes; it applies generally to any existing distortion in the economy. For example, Barnett (1980) explores how the optimal environmental tax on the emissions of a polluting producer are affected if the producer is operating as a monopolist rather than operating in a perfectly competitive market. He find that the optimal emissions tax is less than the Pigouvian tax (the tax with perfect competition and no other distortions). This occurs because an emissions tax tends to reduce the output of the producer. If the producer is a monopolist, then output is already below the social optimum, so that the emissions tax exacerbates this distortion.

Distributional Issues and Nonlinear Income Taxes

In line with the literature on second-best optimal taxation without externalities, the optimal tax rules in the presence of externalities have been extended to consider nonidentical individuals and the introduction of nonlinear income taxes.

Ramsey taxes with nonidentical individuals | In the Ramsey model with identical agents, it is unclear why the government would not use a lump-sum tax to raise revenue. The usual objection to a uniform lump-sum tax is that it is regressive, but there are no distributional worries with identical consumers. Having nonidentical consumers who differ in their wage rates (and also tastes) allows distributional concerns to be incorporated and motivates the reason for not using a uniform tax. Taxes are set to maximize social welfare, with distributional concerns reflected by assigning individuals or groups different weights in the social welfare function. Thus both efficiency and equity affect the tax structure.

With nonidentical individuals, the adjustment to the Pigouvian tax for the presence of other distortionary taxes has several parallels with the identical consumer case, namely:

1. The MCPF term (which still reflects the social costs of raising an additional dollar of revenue, where this is now measured as the average social cost across all individuals).
2. The effect of environmental quality on the existing tax bases.

An additional adjustment enters through a component that accounts for the relationship between the individual's marginal social utility of income and marginal valuation of the environment relative to the average of the population. If individuals with a high marginal social valuation of income also value environmental improvements more than average, this implies a higher environmental tax. If, as is normally the case, the marginal utility of income decreases with income, the environmental tax should be higher/lower than the Pigouvian tax, depending on whether the poor value environmental improvements more or less than the rich do. This result makes sense intuitively—it simply says that improving the environment carries more weight if it redistributes to the poor.

Proost and Van Regemorter (1995) raise the point that an important difference from the representative consumer case in the issue of tax reforms is that recycling revenue from a tax on the dirty good (t_D) as a lump-sum subsidy is not necessarily welfare-inferior to recycling the revenue to lower the labor tax (t_L). If distribution were not an issue, the weak double-dividend proposition would hold. However, when distribution is an issue, progressive transfers can generate equity gains that outweigh forgone efficiency gains.

The expressions for the optimal Ramsey part of the taxes are not particularly easy to interpret, and depend on *aggregate* compensated demand elasticities and the relationship of consumption and labor supply to the net social marginal utility of income.

Nonlinear income taxes | So far, taxes on labor and goods have been linear. Commodity taxes are generally constrained to be linear because of the problem of observing individual aggregate purchases of goods. But there is no reason why income tax *should* be linear. Many countries have income taxes that vary with income, as would seem natural if redistribution of income is an aim. If a first-best, optimal nonlinear income tax was available, then all revenue raising and redistribution could be done without efficiency worries and the optimal environmental tax would again be at the Pigouvian level. However, earning ability is usually unobservable and income tax is leveled instead on total earnings. This introduces an incentive constraint into the setting of the income tax—if tax increases with income, higher earners are deterred from working. Pirttila and Tuomala (1997) consider this case.

III. GENERATING A DOUBLE DIVIDEND

Early analysis of environmental taxation assumed that recycling revenues from an environmental tax to reduce existing distortionary taxes would lead to a double dividend by ignoring the feedback to factor markets from the environmental taxes' price effects (Nordhaus 1993; Repetto et al. 1992). The first study to highlight the relevance of these "tax interaction effects" in the double-dividend debate is Bovenberg and de Mooij (1994), who explore the double-dividend question in the context of the simple model described in the section "Introducing an Environmental Tax" in chapter 2. Bovenberg and van der Ploeg (1994), and Parry (1995) have also studied this question.

We restate in this section the results in Bovenberg and de Mooij. They normalize the tax on C to zero, and, for simplicity, make assumptions[3] that generate a zero-Ramsey component of the environmental tax, leaving only the environmental component, so $t_D = t_D^E$. Intuitively, the assumptions mean that a *uniform* commodity tax (or equivalently, a tax on wages) is optimal.

As stated above, $t_D^E = (t_D^P / \Gamma)$ and, in this model, the MCPF at the optimum is given by

$$(1 / \Gamma) = 1 + (t_L / L) (\partial L / \partial t_L)$$

so it will be greater than one if the labor supply curve is upward-sloping, so that

$$(\partial L / \partial t_L) < 0.$$

The optimal tax formula gives a positive tax on labor and the dirty good. Starting from a position where the labor tax is greater than optimal, and the tax on the dirty good is smaller than optimal, a small increase in the dirty good tax and a small decrease in the labor tax would raise welfare. For a strong double dividend from environmental taxation to arise, however, would require that this adjustment in taxes improve not just overall welfare, but both the environmental *and* the nonenvironmental aspects of welfare. If taxes had been optimally set to ignore

3. The assumptions are weak separability of consumption from leisure, and homotheticity in consumption. The resulting restrictions imposed are that the choice between buying C or D is independent of the individual's leisure time; and that the share of income devoted to C and D does not vary as income.

environmental considerations, only a labor tax would be imposed. Starting from the "nonenvironmental optimum," i.e., $t_D = 0$, marginal revenue-neutral changes in taxes have no effect on nonenvironmental welfare. In this context, starting from a positive tax as the dirty good suggests, an increase in t_D (and a reduction in t_L) reduces nonenvironmental welfare. In this model, *there is never a (strong) double dividend from increasing the tax on D,* although there is a weak double dividend.

The intuition for this result suggests why a labor tax alone is the optimal revenue-raising tax. The final burden of the tax is independent of whom the tax is initially levied on. Ultimately, our interest is in the final incidence of the tax. In this model, labor bears the ultimate burden of any tax in the form of reduced real wages—a wage tax directly reduces the real wage, and a tax on the dirty good increases the price of consumption, which also reduces the real wage. Both taxes involve an efficiency cost because they distort relative prices and, therefore, behavior. Raising the wage tax reduces the supply of labor, which erodes the base of the tax. Raising the tax on the dirty good reduces the real wage, thus people consume less and the tax base is reduced. Also, consumers substitute away from the dirty good toward the clean good, which erodes the base even more. In other words, both taxes are ultimately a wage tax, but the tax on the dirty good is a less efficient revenue raiser because it has a narrower base. There are more ways to "escape" paying the tax because there are more things to substitute away to—the labor tax distorts the consumption/leisure decision, but the tax on the dirty good distorts the consumption/leisure decision *and* the choice between the clean and dirty consumption good. Because the dirty good tax is more distorting than the wage tax, collecting an equivalent amount of revenue using the tax on the dirty good causes a higher dead-weight loss and reduces the real output of the economy more than using the labor tax. In the context of a revenue-neutral swap between the two taxes, the wage tax cannot be reduced enough to compensate for the effect on the real wage of the increased tax on the dirty good. Hence, the real wage, and thus nonenvironmental welfare, declines.

In this example, imposing or raising an environmental tax never generates a double dividend because of the restrictions imposed on the utility function (and price normalization) that generates a zero optimal tax on the dirty good, with labor being the only other source of tax revenue. Thus, increasing the tax on *D* and reducing another tax can never improve efficiency. However, this need not generally be the case. A double dividend will arise from suboptimal initial situations, as is likely to be the case in practice. We can look for starting points from which an increase in the environmental tax and a reduction in another tax can improve the efficiency of tax collection (as well as the environment). Compared to the example above, this could involve situations where the optimal revenue-raising tax on *D* is greater than zero or the introduction of additional tax bases. Following from the latter, if we particularly want an increase in an environmental tax and a reduction in the tax on labor to yield a double-dividend, then it might help to find situations where a labor tax alone is not the optimal revenue-raising tax.

Even in the simple model, a double dividend would be available if both the Ramsey and the environmental part of the tax on the dirty good are positive at the optimum. This occurs when the starting situation is suboptimal (i.e., when $t_D < t_D^R$) from which a revenue-neutral increase in t_D and reduction in t_R improve both the quality of the environment and the leisure/consumption trade off. For a more general utility function in the simple model, the sign of the Ramsey component of the tax on D is determined by the sign of $(\varepsilon_{CL} - \varepsilon_{DL})$, where ε_{ij} denotes the compensated demand elasticity of i with respect to the price of j. Therefore the dirty good should be taxed (or subsidized) depending on whether it is more (or less) complementary to leisure than the composite consumption good C.[4]

GENERATING A POSITIVE DOUBLE DIVIDEND

In this section, we review basic assumptions in the general double-dividend literature, and consider cases where relaxing these assumptions raise the likelihood of generating a positive double dividend:

1. All consumers are identical; utility is increasing in consumption and leisure; consumption goods (treated as a composite good) are equal substitutes for leisure.
2. Utility is a negative function of E (equivalently, the negative of environmental quality), and $E = f(D)$, where $f' > 0$. Utility is weakly separable between the level of the externality, E.
3. The production function is constant returns to scale; and labor is the only primary factor of production (a clean and a dirty good are usually assumed to be inputs).

4. A second way of generating a positive Ramsey tax on D may seem trivial, but it illustrates the importance of price normalization since any good can be set to act as numeraire. Keeping the original form for utility, suppose instead that the tax on labor was normalized to zero. With a zero wage tax, revenue considerations dictate a *uniform* commodity tax (the "Ramsey" part of the taxes on C and D are identical, i.e., $t_C^R = t_D^R = t^R$). Because the Ramsey component of the tax on the dirty good is now positive, initial suboptimal positions (when $t_D < t_D^R$) from which a revenue-neutral increase in t_D and a reduction in t_C would improve both the quality of the environment and the leisure/consumption trade-off. Thus, the particular form for optimal taxes depends on the normalization. It is worth stressing that when the MCPF is greater than one, the *environmental* component of that tax is smaller than it would be if only the environment were being considered, although the optimal tax on the dirty good may be greater then the Pigouvian tax when $t_D^R > 0$.

Consumption Goods

Two features of the first set of assumptions are relevant: equal substitutability of all consumption goods with leisure, and the treatment of all consumption goods as a composite good. Relaxing the equal substitutability assumption implies that taxing those sectors whose output exhibit relatively weak substitutability with leisure raises the likelihood of a double dividend. This occurs because the "tax interaction" effect is weakened relative to the revenue recycling effect since the welfare loss from the tax is offset by the labor supply response. In practice, agricultural output (and natural resources) may exhibit relatively weak substitutability (and complementarity) with leisure, and would therefore represent cases where environmental taxes would generate a positive double dividend.

In the United States, expenditures on housing and health are favorably treated by allowing the deduction of mortgage interest and by excluding health insurance premiums from the income tax. Parry and Bento (1999) analyze tax-favored expenditures by relaxing the assumption of a single composite good. They characterize goods into two classes: goods that are deductible from labor taxes, and goods that are not tax deductible. The dirty good (and a clean intermediate good) are used in the production of both types of consumption goods.

In this model, the authors find that allowing tax-deductible expenditures substantially reduces the estimated costs of revenue-neutral environmental taxes. The key insight is that a lower labor income tax rate reduces both the labor supply distortion and the consumption distortion. The latter occurs because a lower income tax rate raises the price of tax-favored consumption. Because the amount of tax-favored consumption is greater than the socially optimal level, less consumption of these goods raises social welfare. A second point is that while the feedback effect in the labor market is the same as in the basic analysis, no additional distortion need arise in the consumption of the tax-favored good. This latter effect would occur if both types of consumption goods have the same intensity in the dirty good. This assumption is not innocuous, however. The prospects of a double dividend are largely diminished in the extreme case where the dirty good is not used in the production of the tax-favored good.

Nonseparability of Environmental Quality

The second assumption is that environmental quality is separable from consumption and leisure. It is relatively straightforward to make a case that environmental quality should not be treated as separable from leisure and consumption. In the case of leisure, the typical examples of nonseparability include the effect of health status and of road traffic congestion costs on work-related decisions. An improved air quality may have important effects on health status that are then translated into an increased supply of labor through, for example, fewer sick-leave days. Also, if road traffic exacts congestion costs that workers consider part of the fixed cost of working, then improved road traffic may translate into a higher participation rate in the labor market. (See Parry 1998 for an interesting discussion of these issues.) He argues that preliminary results show that "excluding the direct benefits from reduced congestion—the overall costs of the revenue-neutral fees on worker-related congestion can be negative, even for quite significant reductions in road traffic volumes." Restricting the utility function to be separable in this form therefore matters in an important way for the potential to generate a double dividend.[5]

If the assumption of nonseparability is dropped, the Pigouvian tax must be adjusted in two ways:

1. Divided by the marginal cost of public funds as before;
2. To account for the effect on tax revenues from the relationship between the dirty good and labor. When an improved environment raises the supply of labor (as in the case of improved road traffic), tax revenues rise because a higher tax on the dirty good erodes the tax base less than first-round effects would suggest; overall this effect implies a higher environmental tax. The opposite is true, however, if environmental quality and dirty goods or labor supply are substitutes (e.g., individuals take more leisure time).[6]

5. If the assumption is relaxed, the formula for the environmental part of the tax on *D* becomes:

$$t_D^E = \phi\,[(1 / \Gamma)\, t_D^P - (t_L \partial L / \partial E + t_D \partial D / \partial E)] \qquad (1)$$

where $\phi = [1 / (1 - \partial D / \partial E)]$ and is the feedback effect of environmental quality on the demand for dirty goods. Substituting $t_D = t_D^R + t_D^E$ and rearranging gives:

$$t_D^E = (1 / \Gamma)\, t_D^P - (t_L \partial L / \partial E + t_D^R \partial D / \partial E) \qquad (2)$$

6. Note that this effect applies only to the revenue-raising part of the tax on *D*. When the expression for t_D^E is written as in equation 1 in footnote 5 above, the effect of the environment on revenues applies to the whole of the tax on *D*, and $\partial D / \partial E$ also enters directly via the feedback effect ϕ. Taxing *D* reduces the demand for dirty goods and improves the environment, but if an improved environment raises the demand for dirty goods, then this counteracts the initial benefits and reduces the optimal environmental tax. When the expression is rewritten in terms of t_D^R (as in equation 2 in footnote 5 above), the feedback effect drops out. Intuitively, the feedback effect of *E* on *D* and the effect of this feedback on the revenue from the environmental part of the tax on *D* cancel each other out. The environmental part of the tax is set so that the erosion of the tax base from a marginal increase is just equal to the environmental benefits of a reduction in the consumption of *D*.

Production

In the discussion so far, the only possible tax reform has been between the tax on the dirty good and the tax on labor (given the normalization on the clean good). One avenue the literature has pursued is to expand the range of tax bases in the economy, which, in turn, expands the variety of possible suboptimal starting positions. In particular, the simple model has labor as the only input to production. This does not allow for substitution between labor and other inputs in production, which is obviously an important consideration, particularly to the question of obtaining an employment dividend.

Bovenberg and Goulder (1996) extend Bovenberg and de Mooij (1994) to include clean and dirty intermediate inputs in a constant returns-to-scale production function. *This restriction on the production function does not change the basic results.* It is not well known to economists that introducing intermediate inputs in a constant returns-to-scale production function does not change the form of the Ramsey results—production should be efficient and hence only final goods, and not intermediate goods, should be taxed (Diamond and Mirrlees 1971). So again, given the assumptions in the model, only labor should be taxed for revenue-raising purposes. Hence increasing the tax on the dirty consumption good or the dirty intermediate good and reducing the tax on labor cannot improve the revenue-raising efficiency of the tax system since, from an efficiency point of view, the tax on these goods should be zero. Again, all taxes are basically a tax on labor. A tax on intermediate goods reduces their use in production, which makes labor less productive and reduces the wage. A tax on the dirty intermediate good distorts both the labor supply decision and the choice of other inputs to production, whereas an explicit labor tax does only the former.

Bovenberg and de Mooij (1998) have a similar model that focuses on the production side (there is just one consumption good that does not generate externalities). They have two inputs to production in addition to labor, which they call clean capital and a polluting resource. The polluting input is supplied perfectly elastically on world markets, so its pretax price is fixed (or it could be modeled as an intermediate input instead). Two extreme cases are analyzed for the supply of clean capital.

1. It too is perfectly internationally mobile, so its market price is fixed at the world price (this could apply, for example, to financial capital in a small, open economy).
2. Capital is perfectly immobile internationally, and is supplied completely inelastically (for example land, or physical capital in the short term).

Case 1 | This case is very similar to Bovenberg and Goulder (1996) except that suboptimal initial positions are explored in more detail. Labor is the only factor that is not perfectly elastically supplied, hence for revenue-raising efficiency, only labor should be taxed and not capital or resources. Including environmental concerns, the polluting resource should also be taxed. We know from an efficiency point of view that an increase in the tax on the resource and a reduction in the labor tax is a move in the wrong direction. Owners of the resource do not bear the burden of a resource tax since its pretax price is fixed. Again, labor is the only factor that can bear the ultimate burden of taxation. A resource tax is an implicit tax on labor—it results in less use of the resource, which lowers labor's marginal product. Again, a tax on the resource is an implicit labor tax, which is less efficient at collecting revenue than a direct labor tax since it has a narrower base—the labor tax cannot be reduced enough to compensate for the effect on real wages of the increased resource tax. Bovenberg and Goulder go on to explore changes from suboptimal starting positions where there is a positive tax on capital.

Starting from a zero or positive pollution tax, labor is undertaxed[7] (since for tax efficiency, only labor should be taxed, but here both capital and possibly resources are also taxed). An increase in the pollution tax and a reduction in the labor tax still looks like a move in the wrong direction from an efficiency point of view, but there is now a second channel through which nonenvironmental welfare is affected. Now that capital is taxed, the capital market is also distorted and so the tax reform will help improve nonenvironmental welfare if it results in an increased demand for capital, since this increases an existing tax base and thus allows more reduction in the labor tax. It is unlikely, however, that increasing the pollution tax and reducing the labor tax will increase the demand for capital. A far more direct way to stimulate capital demand would be to reduce the capital tax rather than the labor tax. As labor is already undertaxed, it is unlikely that a further reduction in the labor tax will improve matters, whereas reducing the tax on overtaxed capital might.

A revenue-neutral reduction in the capital tax and an increase in the pollution tax is most likely to deliver a double dividend (increase the use of capital and labor and decrease that of the polluting input) if preexisting capital taxes are large compared to pollution taxes, and if capital is elastic in demand relative to pollution (which requires that compared to pollution, capital is a good substitute for labor).

7. Of course, in this model, labor bears the final burden of all taxes since it is the only factor that is not perfectly elastically supplied. A tax on capital does not alter its post-tax rate of return (it is fixed on world markets), but does reduce the demand for capital. It is in this sense that the "burden" of taxation on capital is too high and that on labor too low.

Roughly speaking, from an efficiency point of view, neither pollution nor capital should be taxed, but especially not capital since it is more elastically demanded. Although increasing the pollution tax is "wrong" for efficiency, the initial tax is small and pollution is relatively inelastically demanded, so the extra distortion from increasing the tax is not too bad compared to the possible gains from reducing the high tax on the elastically demanded capital.

The conditions necessary for a double dividend mean that production will be boosted—both capital and pollution are infinitely elastic in supply, but capital is elastic in demand compared to pollution. Hence production is boosted since the price of the inelastically demanded factor is raised and the price of the elastically demanded factor is reduced. In addition, the fact that pollution is a poor substitute for the other two inputs means that the negative substitution effect on its use when its price is increased will be relatively small (which also means the environmental dividend will be relatively small). Perversely, if capital is a *much* better substitute for labor than pollution is, then the positive effect of increased production on the use of the polluting input may outweigh the negative substitution effect from increasing its price, so that the use of the polluting input actually increases. Hence, although the efficiency dividend is achieved, there is actually a negative environmental dividend.

The basic point here is that, with many inputs to production, altering the price of one input has effects on the use of other inputs that depend on the degree of substitutability between these inputs in the production function (given output), and on the general-equilibrium effect on output.

Case 2 | Ignoring environmental considerations, all revenue should be raised from a tax on capital. Since capital is perfectly inelastically supplied, taxing it involves no distortionary costs (a profit tax amounts to a lump-sum tax). Including environmental considerations, the tax on the resource is simply equal to the Pigouvian level, since there is no other distortionary taxation. But such a solution may require a greater than 100 percent tax on profits, depending on the revenue requirement. If profit taxes are constrained to be 100 percent, then this effectively brings us back to a situation with just resources and labor, since owners of capital cannot now bear the burden of other taxes. Thus, from an efficiency point of view, any extra revenue should be raised from a labor tax (since the resource is perfectly elastic in supply), but including environmental considerations means the resource should also be taxed.

This case is essentially the direct opposite to the first case. Now capital, not labor, should be taxed for nonenvironmental optimality. Therefore, we can have suboptimal starting points where labor is overtaxed and capital is undertaxed, so that a reduction in labor taxes could improve nonenvironmental welfare. Whereas in the first case, labor was the only factor that was not perfectly elastically supplied and so always carried the ultimate burden of all taxation, here the burden of an increased pollution tax can be shared by both capital and labor (if capital is taxed at less than 100 percent). A double dividend would occur if the tax change shifted the burden of taxation from labor (which is overtaxed) to capital (which is undertaxed). In these circumstances, using the revenue from an increased pollution tax to reduce the labor tax is likely to help shift the tax burden away from labor and toward capital—reducing the labor tax directly reduces the burden on labor, whereas the increased pollution tax burden is shared between labor and capital. In case 1, increasing the pollution tax reduced labor's marginal product, and the labor tax could not be reduced enough to make up for this reduction in the wage. Now, the effect of the pollution tax on the wage is ameliorated since part of the burden is borne by capital, so it may be possible to reduce the labor tax enough to the increase the real wage. Note that an increase in the real wage and employment may not be enough to raise overall nonenvironmental welfare since profit income (which it is assumed accrues to households) might fall.

Bovenberg and de Mooij show the following conditions need to hold for a double dividend from an increased tax on pollution and a reduced tax on labor to be likely. The fixed factor must be able to bear a large part of the burden of the environmental tax, which requires a small profit tax and a large production share for the fixed factor (i.e., large profits). There should be a large initial labor tax and a small pollution tax, and the labor supply should be elastic. Labor demand should be elastic relative to the demand for pollution, which requires that, compared to pollution, labor to be a better substitute for capital.

FURTHER CONSIDERATIONS

As we have seen, an improvement in the efficiency of the tax system from the revenue-neutral swap is only available if the tax system was initially suboptimal from a nonenvironmental point of view. The new/increased tax should be more efficient (subject to any distributional concerns) than the tax it replaces. This result depends on the final incidence of the taxes (and hence on supply and demand elasticities, which in turn may depend on the degree of substitutability between inputs to production and inputs to utility (goods, leisure, environment, etc.). These basic principles are nicely illustrated by the simple models presented above, but there are clearly many further complications to consider.

The Labor Market

Policy interest in a double dividend has often focused on the possibility of obtaining a second dividend in the form of a reduced unemployment level. Many of the theoretical models employ a perfectly competitive labor market, and so all unemployment is voluntary. With no other source of income than wages, as in Bovenberg and de Mooij (1994), an increase in the real wage must improve nonenvironmental welfare. This will also increase employment if the labor supply is upward sloping; increased employment indicates improved nonenvironmental welfare. It is worth noting, though, that it need not always be the case that increased employment is synonymous with improved nonenvironmental welfare—take this simple model with backward sloping labor supply (although empirical results tend to suggest that the labor supply is upward sloping).

Far from being perfectly competitive, it is generally thought that the European labor market has been characterized by prolonged periods of involuntary unemployment. In addition, labor is far from homogeneous. There are different types of labor (for example skilled or unskilled) that might have different substitutabilities with other factors of production. The precise nature of the labor market will affect the outcome of the environmental tax reform. Some of the literature on the double dividend incorporates labor market imperfections. The way in which the labor market is modeled tends to mean that a wage tax becomes less desirable from a revenue-raising point of view than in the simple model.

Bovenberg and van der Ploeg (1996) use a model that is basically identical to the fixed factor case in Bovenberg and Goulder (1996), with an extreme assumption made on the supply elasticity of labor, namely that it is supplied with infinite wage elasticity, which naturally increases the undesirability of taxing labor for revenue efficiency. This means after-tax wages are fixed, and it is assumed that they are fixed at too high a level, which causes involuntary unemployment. In this case, wages cannot bear the burden of taxation, since the after-tax return to labor is fixed. Although increasing the pollution tax tends to reduce the use of the resource, which in turn affects labor's productivity, this can only be reflected in a reduction in labor demand rather than a fall in the producer wage since this is fixed given the wage tax. Hence all the burden of the environmental tax is passed on to capital by reducing profits. This increases the likelihood of a double dividend from increasing the pollution tax and reducing the wage tax when capital is initially undertaxed. Again, even if employment rises, overall welfare may not increase, since households' profit income is reduced. In addition, the reduction in profit income increases the notional labor supply, so although there is an increase in employment, involuntary unemployment may actually increase.

Nielsen et al. (1995) use an endogenous growth model with involuntary unemployment caused by unions having monopoly power in wage setting. Unions and firms bargain over the wage and firms then choose employment. Unions maximize the utility of a representative member (the probability of being unemployed and receiving unemployment benefit plus the probability of being employed and receiving the wage).[8] They thus trade off high wages against increased unemployment. There is involuntary unemployment since people would like to supply more labor at the going wage rate. When benefits are untaxed, the bargaining outcome is such that the post-tax wage is a constant markup over benefits independent of the wage tax rate. Thus, again, the post-tax wage is rigid at too high a level, but the process by which this occurs is modeled explicitly. This again means that an increase in the environmental tax and a reduction in the wage tax can reduce emissions and decrease involuntary unemployment.[9] Because the post-tax wage is fixed, all reductions in the wage tax feed through to a reduction in the producer wage, which increases the likelihood of increased employment. If, instead, benefits were subject to the same tax as wage income, then a reduction in the wage tax would also make the outside option of unemployment more attractive, thus unions would increase their wage claims in a way that left the producer wage unchanged.

However, although it is possible to achieve an environmental improvement and an increase in employment, this is accompanied by a fall in the growth rate of the economy. Lower pollution in production reduces capital productivity, which is not fully set off by higher employment. The drop in the rate of return reduces capital accumulation, which outweighs the positive effect on the growth rate of increased employment.

Bovenberg (1995) describes a model in which there are inactive households that receive benefits and active households that work and receive only wage income. The reason for nonparticipation in the labor market is not modeled explicitly. Again, only

8. In fact, rather than have unemployed and employed members, everyone works, but for fewer hours than they would like to at the going wage (work-sharing)—but the two situations are identical in aggregate.

9. Note that this model does not actually explore revenue-neutral tax changes, since public spending (which includes spending on pollution abatement) is optimized rather than set exogenously. In addition, the production function is such that there is a unit substitution elasticity between pollution and other inputs. Hence, pollution revenues are unchanged by changes in the pollution tax rate. In this model, what makes a reduction in the labor tax possible when pollution taxes are increased is that less pollution in production reduces the optimal public spending on abatement, thus lowering the revenue requirement from the labor tax.

wages and not benefits are subject to the income tax. There is a clean consumption good, and a dirty consumption good, which is subject to a tax. The fact that benefits are untaxed now plays a different role in increasing the chances of a double dividend. Here, from an efficiency point of view, a uniform commodity tax would be optimal, but this is not equivalent to a wage tax since benefits are untaxed. A reduction in the wage tax benefits active households only, whereas an increase in the tax on the dirty good acts to reduce the real income of both types of households. The burden of the dirty good tax is not borne by workers alone and so it may be possible to reduce the wage tax enough to increase real wages overall. The base of the dirty good tax, relative to the wage tax, is broadened compared to the simple model.

Marsiliani and Renstrom (1997) incorporate all three of the above effects. There is a fixed factor in production and no profit tax. Wages are set via union bargaining over wages and the unemployed receive untaxed benefits. The wage-bargaining process is generalized to allow the degree of union power to vary. Thus the real post-tax wage is fixed independent of the wage tax at a markup over benefits, which depends on the degree of union power. There is a tax on dirty consumption and on a dirty production input with a fixed real pretax price. The only other tax is a wage tax. There is imperfect competition, which results in a constant markup of producer price over cost, depending on the degree of imperfection (from monopoly to perfect competition). They find that a revenue-neutral increase in the environmental tax from a zero level and a reduction in the wage tax yields a double dividend even if both the product and labor markets are perfectly competitive. However, the degree of monopoly power in both markets increases the size of the double dividend. Imperfect competition in the product market increases the price elasticity of the labor demand relative to the cross-price elasticity with respect to the energy price. It also increases the profit share in production, which makes it easier to shift the burden of taxation toward profits. Also, increasing the profit share means that a smaller proportion of household income comes from wages and increasing union power increases unemployment, which also reduces the proportion of wage income in total income. This broadens the base of the dirty good tax compared to the wage tax.

CONSUMPTION TAXES

Bovenberg and de Mooij (1994) look at a consumption tax. In general, a consumption tax increases the price of the good, which thus reduces consumer purchasing power. This may make people demand less of that good, which may reduce the producer price (ameliorating the increase in consumer price to some extent). This affects the producer who must pass the incidence on either to labor (reduce wages) or capital (reduce profits). The effect on the real wage depends on the increase in consumer price and the reduction in wages. They do not distinguish between consumers and workers, so that a price increase or wage reduction have identical effects, and a switch from the broad-based labor tax (there is no capital tax) to the narrow-based tax on *D* reduces the real wage. In reality, consumers and workers are not identical. Consumers get income from a variety of sources (from working, from capital, from government benefits, etc.) and so nominal effects on prices, wages, and profits may not have the same real effects on everyone, depending on the composition of their income.

The effect on producers depends on questions of country size, international trade, and border tax adjustments. For a small country producing an internationally traded good where taxes are adjusted at borders, consumers bear the entire burden of a consumption tax, since producers can always sell their product at the world price. If there were no border tax adjustments, domestic producers (therefore labor or capital) bear the entire burden since consumers can always buy at the world price (which is unaffected by the small country introducing a tax). On the other hand, a large country, or group of countries may affect the world price by introducing a tax, so some of the burden will be borne by producers (labor and capital) abroad as well as at home. The country can improve its terms of trade depending on whether it is a net importer/exporter of the good.

The environmental tax could also be on production, such as taxes on intermediate inputs or on resources, like the tax on polluting resources in Bovenberg and Goulder (1996). Unless the resource is perfectly inelastically supplied (so all the incidence is on the resource owner) the tax increases production costs and some of the tax burden will have to be passed on to consumers (by increasing the price of the final good being produced), labor, or capital. Again this depends on international aspects—if there is a fixed world price for the good, then producers can pass all the tax on to domestic consumers. If producers have to absorb some of the effect by reducing prices, then this will pass on to labor or capital.

As the authors illustrate, the extent to which tax incidence bears on labor versus capital will depend crucially on supply elasticity factors. Financial capital and resources (such as energy) tend to be mobile internationally (particularly in the long term), whereas labor is less mobile, and so would bear the burden. On the other hand, physical capital is also likely to be immobile in the short term. In this case, whether labor or capital bears more of the burden depends on their relative substitutability for the resource. If, for example, capital and energy are complements (as empirical evidence tends to suggest), then capital bears the burden.

However, Bovenberg and Goulder (1996) do not address the issue of capital in any dynamic sense. It is either a fixed factor like land or is perfectly elastically supplied at a world price (therefore, it must always receive the same rate of return). Capital does not exist as a result of dynamic decisions over consumption versus saving and investment in these models. In a dynamic model, a drop in the rate of return on capital might reduce investment, as described by Nielsen et al. (1995), and hence decrease labor productivity and therefore wages as well as, perhaps, growth.

Smulders (1995) discusses endogenous growth and environmental degradation incorporating endogenous technical progress. The literature on technological progress, as developed by Romer, allows for the creation of new technologies, which enhance the productivity of inputs. Such innovation requires investment, but once created, new knowledge is nonrival in use (i.e., it can be used by anyone at zero marginal cost) and may also help in the creation of the next innovation. Smulders models the environment as a stock of natural resources. This stock is affected by the use of natural resources as an input to production, and because the environment is used as a sink for the pollution created during production. In addition, the environment can regenerate to a certain extent. The state of the environment may also enter the production function in a way that does not deplete it—for example a clean environment can improve health and therefore labor productivity. So environmental quality is also a public good that affects productivity in a nonrival way. Without technological progress, economic growth would require the use of even more environmental resources, which would not be sustainable. However, with technological progress, ever more output can be produced from given inputs and sustainable growth may be possible. In such a world, a more stringent environmental policy (for example, taxes) could improve the environment and result in a higher steady-state rate of growth depending on the balance of two conflicting forces that Smulders identifies.

Environmental taxes bias innovation toward developing resource-saving technology at the expense of other research and development, which tends to harm growth. But, because the stock of natural resources provides both rival and nonrival inputs to production, an improvement in the environment boosts productivity (and hence investment), which has a positive effect on growth. An increased steady-state growth rate occurs when the latter effect dominates.

Carraro et al. (1996) also suggests that dynamic analysis of a trade-off between environmental taxes, employment, and growth may be misguided if it does not allow for endogenous technological progress. If endogenous technological progress is included via innovation, then shifting taxes away from labor and toward pollution may stimulate investment in environmentally friendly technology, which can boost the growth rate of the economy and have consequences for employment, depending on whether this new technology is labor saving or not. Moreover, any positive effects on economic activity and income induced by changes in growth or employment may act to offset the environmental benefit from the increased environmental tax.

Fullerton and Metcalf (1997) point out that there may be many other types of policies in place apart from existing taxes when an environmental tax is introduced, and it is important to consider the interaction of new taxes with all existing policies. For example, take the simple Bovenberg and de Mooij (1994) model and assume that pollution had been reduced by restricting production of the dirty good *D* rather than by taxing it. A quantity restriction is equivalent to taxing the dirty good, except that instead of the government receiving the tax revenue, this revenue goes to producers as a scarcity rent. Because production of the dirty good is restricted, firms can charge consumers more than it costs to produce *D* by exactly the same amount as the tax that would achieve the equivalent outcome (call this the shadow tax). A 100 percent profit tax is equivalent to both a tax on *D* and a tax on *L,* thereby meeting the revenue requirement. If the government introduces the quantity restriction, taxes profits at 100 percent and uses the revenue to reduce the labor tax, then this is the same as a revenue-neutral swap between the tax on labor and the tax on the dirty good. If the government introduced the quantity restriction and producers keep profits, then (assuming profits are distributed to consumers), this would be equivalent to introducing and returning the revenue as a lump sum. Now suppose there is a restriction on production of *D* and producers/consumers keep the profits. If the government introduces a tax on *D* that is below the shadow tax, this does not affect the production or consumer price of *D*; it simply transfers part of the scarcity rent to the government. If they now use the revenue to lower the labor tax, this increases the real wage and reduces the labor market distortion. This more than offsets the reduction in profit income (which is the same as lump-sum redistribution being worse than a reduction in the labor tax). Of course, this does not alter the argument that improvements in the efficiency of the tax system are available only if it was suboptimal in the first place. It merely illustrates that, for example, existing regulatory policies may also be important. In the above example, the tax reform only has the beneficial effect of directly increasing the real wage, without the harmful effect of indirectly reducing it by increasing the price of *D*.

IV. THEORETICAL LITERATURE CONCLUSIONS

The argument for a strong double dividend from environmental taxation sounds intuitively appealing. Environmental taxes correct for distortions in the economy, whereas ordinary revenue-raising taxes tend to create distortions. So, if the revenue from an environmental tax is used to reduce an existing distortionary tax, then there will not only be an improvement in the environment, but also a reduction in the dead-weight costs of tax collection. Theoretically, this argument is flawed. The optimal set of taxes from a revenue-raising point of view can be calculated. The overall optimal set of taxes from a revenue-raising and environmental point of view can also be calculated, which is likely to involve a higher tax on the environmentally harmful good or activity. Suppose the government did not know about the harm from the dirty good. Then it should have been collecting revenue in the distortion-minimizing way. If it now receives news about the environmental externality, then increasing the tax on the dirty good and reducing another tax may well lead to an overall benefit, but it cannot improve the efficiency of tax collection, since this was initially optimal. It is important to realize that, when we abstract from environmental gains, an environmental tax is just like any other tax, and will be associated with a dead-weight cost. If there is a strong double dividend associated with the tax reform, this simply means that there was scope for welfare-improving tax reform even before the government became aware of the problem with the environment. Of course, new information means the tax system should be reoptimized, and we are interested in what the optimal system looks like, hence it is useful to explore questions such as how existing taxes affect the setting of environmental taxes. But a strong double dividend means the tax system was suboptimal even under the old information, and this should be dealt with in its own right rather than needing another reason to change taxes.

Of course, it is perfectly possible that the tax system is not optimally designed, but then there could be all sorts of efficiency-improving tax changes to be had, irrespective of environmental questions. The double-dividend literature often proceeds by presenting initial situations from which the revenue-neutral introduction of an environmental tax yields a strong double dividend, but, as these comments stress, the question of which tax reforms from a suboptimal starting point will improve the efficiency of revenue collection could be explored in these models without environmental externalities.

The particular second dividend that many policy makers are interested in is whether an increase in an environmental tax and a reduction in taxes on labor can achieve an increase in employment. This depends on the final incidence of the taxes (and hence on demand and supply elasticities for final goods and factors of production). Although, superficially, a tax on a resource can encourage substitution of labor for the resource in production, the overall effect on employment depends on supply responses of other factors, demand elasticity for the final good, and so on. As illustrated in Bovenberg and Goulder (1996) the effects of an increase in the resource tax and a decrease in the labor tax depend crucially on the supply elasticity of capital and on the substitutability between capital, resources, and labor in production. An increase in the tax on the resource and a reduction in the tax on labor only increases employment if, for example, labor is overtaxed initially and capital is undertaxed, the production share of capital is large, and labor and resources are easily substitutable.

Their paper draws attention to the importance of simplifying assumptions such as homothetic demand, separability of leisure and consumption, and separability of consumption and environmental quality on results. Dynamic questions about growth, investment, and innovation may be important. Correct modeling of the labor market is important—all priori distortions in the economy matter, not just environmental externalities and existing distortionary taxation. This last point also indicates that all existing policies should be taken into consideration, not just taxation. For example, are there existing environmental policies in the form of regulation?

These are complex issues, but the basic lesson is that the appealing assumption that an increase in an environmental tax and a reduction in a labor tax must increase employment is flawed, since of course it is the final incidence of the environmental tax that is of crucial importance, and many taxes are simply implicit taxes on labor. In addition, many of these theoretical models are set up so that an increase in employment is synonymous with an improvement in (nonenvironmental) welfare, but this does not necessarily have to be the case, and so it is important to distinguish between increases in employment and increases in economic welfare.

Finally, throughout this paper, it has been stressed that if an environmental tax can deliver a strong double dividend, then this is not because it is an environmental tax, but because it is a good revenue raiser and the tax system was suboptimal from a revenue-raising point of view. If the tax system is raising revenue inefficiently, then this is something that should be dealt with in its own right rather than looking for environmental taxes to yield a double dividend. It may be the case, though, that there is an extra bonus in the sense that it is better to use the environmental tax revenue to reduce existing taxes than to recycle it in an efficiency-neutral way, although even this result could depend on equity consideration.

V. EMPIRICAL LITERATURE

Although discussions on the potential employment effects of environmental taxes abound, essentially no research on the U.S. labor market has been done. Much of the empirical work evaluating the employment double dividend from environmental tax reform has been done for European economies. In this chapter, we review existing empirical literature on the double-dividend hypothesis, and discuss issues relevant to the evaluation of its empirical validity in the context of reductions in the payroll tax rate.

EUROPEAN LITERATURE

Concern with persistently high unemployment rates in Europe prompted various proposals to increase energy/carbon taxes with revenue recycling to reduce social security and income taxes. Denmark, Finland, the Netherlands, Norway, and Sweden tax emissions of carbon dioxide, the main greenhouse gas, and recycle the revenues from environmental taxes to reduce taxes on labor. In Britain, a small cut in the payroll tax is being financed by a tax on the disposal of waste at landfill sites.

For the most part, much of the limited empirical literature uses two types of empirical models, which have been used to evaluate the gains from environmental tax revenues. It is useful to characterize broadly macroeconometric (ME) models and computable general-equilibrium (CGE) models. Macroeconometric models use a detailed representation of the demand side of the economy and an aggregate production function for the supply side to examine the impact of policy (and supply) shocks on aggregate demand and supply. Such models are useful in that they simulate the adjustment process of a response to a shock, but are limited because they do not disaggregate the effects on separate factor or asset markets. CGE models take a very different approach and incorporate individual and firm (producer) behavior. Because these models characterize individual preferences and profit-maximizing behavior, they simulate behavior that in principle should be consistent with economic theory. CGE models typically assume mobile labor and instantaneous market clearing.

As a result of these various green tax schemes, empirical research on the labor market effects of various environmental tax proposals is more extensive in Europe than in the United States. Much of the European literature summarized here uses some variant of macroeconometric models. A noticeable pattern from the empirical work is that the employment effects (relative to the baseline impacts of an environmental tax) are almost uniformly positive, with a range of 0.1 to 0.7 percent. In addition to estimates of the total effects of income tax reductions, the literature provides some insights into the rankings of different tax proposals. The results seem to suggest that reductions of employer's social security taxes generate stronger employment effects (relative to baseline) than income tax reductions. One explanation for this effect is that lower income taxes do not (in the models used) affect hours worked, whereas lower social security taxes reduce firm's labor costs, and thereby raise labor demand. Intuitively, however, firms can benefit from lower labor costs only if they are able to substitute different factors in production. In fact, results seem to show that models that allow greater factor substitution (to labor from energy) generate stronger gains in employment.

A commonly used model in the European literature is the Hermes model, a member of the class of macroeconometric models. This model assumes complementarity between capital and energy in production so that combinations of capital and energy are associated with bundles of labor and other intermediate inputs. Factor substitution is limited in manufacturing industries in that factors can be substituted only with new equipment. The effect of an energy/carbon tax (with revenue recycled to reduce employer's social security taxes) can be distinguished into an income effect and a substitution effect. The combination of a higher energy tax and a lower social security tax reduce the relative price of labor in production, and leads firms to substitute to labor from energy and capital. Higher energy taxes reduce real income, demand for all factors of production and, therefore, output.

Net employment effects in this model are in the range of 0.1 percent increase (from baseline) in the United Kingdom to 0.3 percent in France and 0.7 percent in Italy and Germany. In this model, employment rises because of a shift in the labor demand curve by firms, not because of a shift in the labor supply curve. Recycling revenues to reduce income taxes generates smaller employment gains than recycling the revenues to reduce the payroll tax. This occurs because it is assumed that the payroll tax reduces the relative price of labor to the employer.

Another noticeable pattern is that the Quest model generates consistently smaller employment gains from an environmental tax (regardless of how the revenues are recycled). Differences in model projections can be traced to different modeling of the structure of the wage equation (Majocchi 1997), transition dynamics (including the wage-price dynamics), and consumption behavior. Models that restrict the wage-price reaction generate better employment outcomes than models that assume significant responses to prices. Also, modeling consumption as a function of real wealth instead of income explains some of the difference in results.

Between 1990 and 1996, the civilian unemployment rate averaged 11 percent in France, 9.6 percent on Italy, 5.7 percent in West Germany and 9 percent in the United Kingdom. Moreover, these rates are similar to those experienced in these economies during the 1980s. The potential to reduce unemployment rates through a revenue-neutral reduction in the employer's portion of the social security tax has been evaluated in some detail. One study by the EC simulated the economic effects of a 10 percent reduction in social security taxes (1 percent of GDP) and shows increases in employment (relative to baseline) of 1 percent after 7 years. The author's findings of the second study are summarized and presented in table 1 .

TABLE 1: **CHANGES IN EMPLOYMENT BY SECTOR** **(in thousands)**

	Germany	France	UK	Italy	Netherlands	Belgium	Total
Total Employment	234.7	98.8	150.1	165.6	15.2	32.5	696.6
Energy Sector	-0.7	-0.6	0.7	0.0	-0.4	-0.4	-1.5
Industry	70.9	40.8	69.1	24.4	3.1	9.9	218.2
Transport	26.2	5.1	21.1	17.7	2.2	4.7	76.9
Services	76.4	43.4	43.3	90.9	7.9	15.9	277.9

The table presents new employment figures in different countries and different sectors as of 2001, the final year of the simulation. For the six EU countries, the total employment increase of 697,000 workers amounts to a 0.6 percent increase in employment from the carbon tax financed reduction in social security taxes. These models project substantial employment gains. This divergence in estimates between studies likely derives from assumptions about initial conditions, such as unemployment rates. Higher unemployment rates are relevant because they limit the response of the wage to price changes. In most of the models used to examine the employment effects of tax-shift schemes, it turns out that the wage-price dynamics play a key role in determining the impact on employment.

The simulation results summarized above evaluate the employment gains from a proportional reduction in social security taxes and are based on models that treat labor as a homogenous factor. Evidence suggests, however, that unemployment tends to be highest among less skilled workers. An alternative strategy then is to reduce firms' cost of employing less skilled workers. One proposal that has been mentioned is to exempt minimum wages from the employer's social security contributions. Two implementation schemes have been proposed. Under the first proposal, employers would be required to pay the social security tax only on wages above the minimum. Under the second proposal, the exemption would be phased out between the minimum wage and twice the minimum wage. Table 2 presents rough estimates of the economic effects of targeted reductions in the social security tax. These findings suggest that exempting employers from social security contributions for low-wage workers spurs a larger expansion in overall employment. The standing assumption in all exercises is clearly that the incidence of the social security tax in Europe falls not on the worker but on the employer.

TABLE 2: **TARGETED REDUCTIONS IN THE EMPLOYER SOCIAL SECURITY TAX FINDINGS FROM VARIOUS STUDIES**

		Employment (percent change)	
Country	**Targeted Tax Cut**	**Less Skilled**	**Total**
Netherlands		3.5	1
EU-12	40 percent reduction in Social Security Contributions	12.6	2.2
Belgium	1 percent of GDP	9.5	2.1

Source: Majocchi 1997

Before discussing the literature on the payroll tax in the United States, we review the literature most related to the double-dividend hypothesis and discuss its relevant issues.

U.S. LITERATURE

Although similar models have been used in the United States to examine the efficiency value of carbon taxes (Shackleton et al. 1996), they have focused on GDP growth and welfare effects of alternative uses of the revenues. They consider the effects of a carbon tax raising revenues of between $20 billion in 1990 and $85 billion by 2010 (in 1990 dollars). They evaluate several different uses for the revenues: reductions in the form of lump-sum taxes; personal income tax rates; payroll tax rates; corporate income tax rates; and an increase in the investment tax credit.

The authors use four models of the U.S. economy, both macroeconometric and computable general equilibrium. Several important conclusions emerge from their study. First, recycling revenues to reduce labor costs generally dominate recycling to reduce individual payroll or income taxes in determining output effects. Second, model assumptions about technology and labor force growth dominate tax recycling schemes in evaluating the effect on economic growth. A wide range of estimates of the extent of the impact to which revenue recycling options offset the effects of the carbon tax are generated, both across models and across recycling schemes for a single model. The variation across models can be traced to differing assumptions on the following factors:

1. Elasticity of labor supply (the incidence of income and payroll taxes)
2. Elasticity of savings
3. Input substitution (fossil fuels and other inputs)—affect demand for labor and output price
4. Aggregate elasticity of demand for energy (affects output price)

In evaluating these factors, it is important to consider that substantial uncertainty exists in the empirical literature on the elasticities of labor supply and savings.

ISSUES IN THE EMPIRICAL EVALUATION OF THE DOUBLE-DIVIDEND HYPOTHESIS

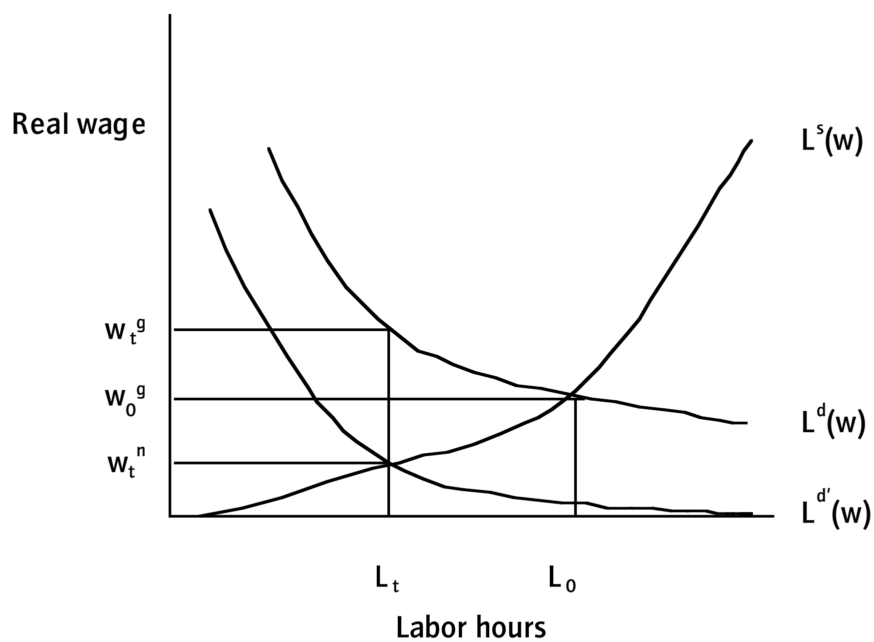
The previous section argued that essentially no work has evaluated the labor market effects of alternative uses of revenues in the United States. A complete evaluation of this is beyond the scope of this paper. Instead, this paper discusses issues in evaluating the potential labor market effects of reducing the payroll tax in the context of an environmental tax shift using results from relevant literatures.

It is argued that the impact of a payroll tax cut will depend on the extent to which the tax is shifted to wages. The shift to wages, in turn, depends on the extent to which workers value (social security) benefits and the responsiveness of the labor supply to the after-tax wage. We review the empirical literature on the impact of the payroll tax, and argue that the likely effect of a payroll tax cut will be on wages rather than on employment.

Conceptual Framework

In evaluating the impact of an environmental tax, it is instructive to think of the labor market effects using a very basic model of the labor market. That model posits that individuals work more hours as the wage rises (an upward-sloping supply curve) and that firms employ fewer workers as the wage rises (a downward-sloping demand curve)—see figure 1.

FIGURE 1: **BASIC LABOR MARKET MODEL**



Starting from the no-tax position (w_0 ,L_0), a tax on a firm reduces the wage at any level of employment, effectively shifting the labor demand curve down. At the new equilibrium, the net wage and labor hours (w_t , L_t) are lower. A reduction in the wage tax would raise the net wage and employment.

In thinking about the effects of an environmental tax, it is important to consider that the tax raises the price of consumption goods, and thereby reduces the real wage (and employment). The net effect of any environmental tax on employment then depends on the relative sizes of the wage and price effects. The empirical literature on the size of these effects (independent of any payroll or income tax changes) is very limited.

We therefore attempt first to evaluate the employment effects of environmental taxes by reviewing empirical analyses of the impact of environmental regulation in the United States.

Environmental Regulation and Labor Demand

The United States historically has relied far more heavily on regulation as a means of improving the environment. While regulation is widely believed to be a less efficient tool than taxes to improve the environment, economic theory suggests that regulation might be preferable to taxation under certain assumptions about uncertainty. Recent work has questioned the validity of these conclusions (Kaplow and Shavell 1998). They show that environmental taxes dominate regulation regardless of uncertainty about the externality-induced harm. In addition to the standard argument that taxes allow individuals to abate at the efficient level, Shavell and Kaplow argue that taxes reveal information about the firm's control costs, thereby making possible the outcome with the optimal externality.

Our idea is that the employment effects of environmental regulation give a lower bound on the employment effects of taxes since regulation is always inferior in efficiency to taxation. We caution that it is difficult to generalize from these findings to thinking broadly about environmental taxes with revenue recycling, largely because the correct comparison would, for example, hold constant the level of emissions reductions. Nonetheless, we review this literature briefly as a means of understanding at least the general direction of possible employment effects.

The most directly relevant literature relates to air quality. Though most environmental regulation in the United States is local, most studies examine the effect of federal regulation on employment. Gray and Shadbegian (1993), Gray (1987), and Bartel and Thomas (1987) examine the effects of the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA). Bartel and Thomas estimate the effects of the EPA and OSHA on wages and profits and find regional differences in their impact. In particular, large firms gain at the expense of small firms in the Sun Belt. Gray and Shadbegian find that manufacturing plants with high abatement costs have low productivity and high labor demand. At the industry level, studies have found that federal environmental regulation reduces labor demand in the copper industry and productivity in electric power plants (Hartman et al. 1979, 1983).

Studies of local environmental regulations have found that states with more stringent enforcement have fewer plant openings (Gray and Hunt 1997) but the location of new manufacturing plants in pollution-intensive industries does not seem to respond to environmental regulation. Also, using data from abatement costs, a number of studies have included an explanatory variable reflecting such costs (along with state and local taxes, existing level of labor unionization, and manufacturing activity, etc.) in regressions trying to estimate the determinants of plant location across different states within the United States. In general, the effects of such costs have not been found to be statistically significant, or significant but small (Bartik 1988, 1989; Friedman et al. 1992; McConnell and Schwab 1990; and Jaffe et al. 1995).

In a recent, convincing study of the South Coast Air Basin (which surrounds Los Angeles), Berman and Bui (1997) study the effects of a large increase in air quality regulations. They compare the change in employment in regulated plants to the change in employment in unregulated plants for different regions, industries, and years. The authors find no evidence that air quality regulation decreased labor demand, and if anything, increased it slightly.

Empirical evidence on the employment effects of environmental regulation is not conclusive, but on balance seems to suggest that the effects are not strongly negative. The issue we address next is the extent to which labor hours (employment) can be increased by a reduction in taxes on labor.

The Social Security Payroll Tax

In 1996 total social security contributions amounted to $500 billion (over 30 percent of federal revenues). Old Age Survivors Disability and Health Insurance (OASDHI) contributions are collected equally from the employer and employee at a rate of 7.65 percent (6.2 on OASDI and 1.45 on HI). Until 1991, the maximum earnings subject to the OASDI and HI tax were set at the same rate of $51,300. By 1996, the maximum taxable earnings subject to OASDI had risen to $62,700, whereas the cap for the HI tax was abolished. Almost 149 million workers paid social security taxes in the most recent year available. Of those, about 95 percent face the social security tax on the marginal hour of work. Because the tax is not imposed on the marginal dollar earned by those at the top of the earning distribution, the social security tax is criticized as being regressive, or inequitable. It is difficult to evaluate the equity and efficiency effects of partially switching from payroll taxation to environmental taxation without specific proposals on the type and size of environmental tax considered. Because the payroll tax is imposed on wage and salary income and such income is not as responsive to taxes as other (unearned) income, the payroll tax is considered relatively efficient. An important feature of the efficiency of the payroll is the link between the tax and the benefits received. In this section, we discuss the economics of the payroll tax and evidence on its efficiency.

Our interest in this paper is to evaluate the potential employment effects (efficiency) of the payroll tax. To do so, it is instructive to think of the basic model of the labor market presented in figure 1. Consider the effect of a payroll tax levied on the firm. The first-round effects of the tax are similar to those of the environmental tax—wages and labor hours decline. The extent to which wages and employment decline depends on the shapes of the labor demand and supply curves. The steeper the labor-supply curve (less elastic), the larger the fall in wages and the smaller the decline in employment. Because payroll taxes provide benefits that workers may value, work hours would increase as individuals work more hours at each wage. In the extreme case in which workers value the benefits at exactly the cost of providing them, we would observe full shifting of the payroll tax to wages (with no change in employment). Moreover, a standard result in public finance is that this outcome is independent of whether the tax is levied on the firm or the worker.

The two assumptions behind this result are that wages are flexible, and that benefits are linked to tax payments (and that workers perceive this link). Neither assumption is universally valid. Wages are clearly rigid downward at or near the minimum wage. Current population survey data for 1997 suggests that about 10 percent of workers earn the minimum wage. For these workers, we might observe employment effects from a payroll tax (and conversely, employment effects from a reduction in the payroll tax).

The second assumption requires (in the case of social security) workers to perceive some link between taxes and benefits. Several studies suggest that this link has been quite strong historically (Burkhauser and Turner 1985). Recent evidence, however, suggests that current workers do not expect any benefits from social security. In the simple model of figure 1, this perceived break in the link between taxes and benefits would reduce the extent to which labor supply shifts in response to payroll tax changes. Alternatively, a cut in the payroll tax may increase employment.

A related point is that the "correct" payroll tax faced by a worker is the present value of all tax payments less the present value of benefits. Only the difference between tax payments and benefits over a lifetime can be considered a tax. Feldstein and Samwick (1992) estimate net social security tax rates by demographic group. Their most striking result is that working married women face essentially the entire payroll tax. This occurs because married women may be eligible to obtain retirement benefits proportional to their husband's, which are often higher than the social security benefits they could obtain based on their own work contributions. Men, on the other hand, generally face low marginal rates for social security. These results are striking because the group that faces the highest marginal tax rates, married women, is also the group whose labor supply is most responsive to taxes (Eissa 1995).

Even with a tight link between benefits and taxes, however, workers would have to plan over a relatively long time horizon for the assumption to hold. If one believes that individuals are myopic, then the effect of a payroll tax is identical to those of a labor income tax.

The relevance of this analysis is that if the payroll tax is shifted to workers, a cut in the payroll tax would not increase employment. Although early evidence is not conclusive (Brittain 1972; Vroman 1974; Hamermesh 1979; and Leuthold 1975), recent evidence on specific programs suggests that that the payroll tax may be fully shifted to workers (Gruber and Krueger 1991; Gruber 1994, 1995). Brittain's finding that the social security payroll tax is fully shifted to wages was criticized by Feldstein (1972).

Vroman conducted a time-series study of wage determination in U.S. manufacturing during 1956 to 1969. He constructed a wage equation where the average hourly wage and salary payments depend on unemployment, prices, profits, the payroll tax (for social security only) and other labor income (e.g., employer contributions to private pension plans). Vroman found evidence of only partial shifting of the payroll tax by employers.

Hamermesh's study uses data from the Panel Study of Income Dynamics to examine the effects of the payroll tax. He estimates an ordinary least squares (OLS) regression of the logarithm of hourly earnings on a vector of socio-economic and demographic variables, and on the current and lagged values of the average payroll tax rate using a sample of 587 adult white men between the ages of 30 and 60. Hamermesh's selection procedures eliminates workers with greater labor supply elasticities, but generates variations in the marginal and average social security tax rates for the fraction of the sample whose incomes exceed the maximum taxable amount.

Accounting for current and lagged effects of the payroll tax, Hamermesh estimates a shift of about 36 percent, suggesting that in the long run about one third of the tax is borne by labor as lower wage rates. Two recent studies provide strong evidence suggestive of substantial shifting of the payroll tax to wages by examining specific programs financed by taxes (Gruber and Krueger 1991; and Gruber 1995). Both studies examine mandated benefit programs. These programs have labor markets effects similar to those of a social security payroll tax.

Gruber and Krueger examine the effects of state Workers' Compensation Insurance (WCI) programs. WCI varies widely across states and over time more than other payroll taxes, and so provides an opportunity to examine more convincingly responses to changes in tax rates. The authors examine wages of carpenters, truck drivers, nonprofessional hospital employees, gasoline station workers, and plumbers, from the 1979 through 1981, and 1987 through 1988 Current Population Surveys. Their results suggest that fully 85 percent of WCI costs are shifted to employees in lower wages. They then use state-level, employer-reported data collected by the Bureau of Labor Statistics to verify their findings from survey data. They again find a shift of about 86 percent; and conclude that employers' WCI costs are largely shifted to employees in the form of lower wages, with no appreciable effect on employment.

In a related study, Gruber evaluates the effects of extending comprehensive health care coverage for maternity on the wages of women of childbearing age and their spouses. That study found almost complete shifting of the costs of maternity benefits to wages, with little effect on employment.

VI. CONCLUSION

This paper examines the potential impact of environmental taxes on labor markets and the validity of the double-dividend hypothesis. While the idea of the double dividend is intuitively appealing, a review of the theoretical literature shows that the hypothesis is not at all obvious. In making sense of the double-dividend argument, it is important to realize that environmental taxes have two of the same attributes as ordinary taxes: they raise revenue, and they alter behavior by changing prices. This change in behavior involves a distortionary cost in the same way as a labor tax—by driving a wedge between consumer and producer prices.

Essentially no work has empirically evaluated the labor market effects of alternative uses of environmental tax revenues. This paper discusses issues in evaluating the potential labor market effects of reducing the payroll tax, financed by an environmental tax. The impact of recycling environmental tax revenues to reduce the payroll tax will depend on several factors, including the extent to which workers value the benefits, and the extent to which the benefits are shifted to wages. Empirical evidence from social insurance programs suggests near-complete shifting to wages with no impact on employment. It is unclear then whether such a tax shift will have any impact on employment. Extensive further research needs to be done before statements about the labor market effects of environmental taxation can be validated.

APPENDIX

NONLINEAR INCOME TAXES

Suppose there are two types of consumers, of high ability (i.e., high wage) and low ability (i.e., low wage). Preferences are identical so that individuals differ only in earning ability. Again, the first-best Pigouvian tax would equal the sum of marginal environmental damage over the two types:

$$t_D{}^P = -\sum_i (V_E{}^i / V_M{}^i) \equiv \sum_i MV^i$$

Suppose that the government is constrained to set an income tax on observed earnings. Type $i, I = h,l$ earns I^i thus $L^i = I^i / w^i$, and has after-tax income $M^i = I - T(I)$ where $T(I)$ is the income tax schedule.

The optimal tax problem for the government is to choose I^i, M^i and t_D to maximize the social welfare function $W(V^l, V^h) = V^l + \delta\ V^h$ (i.e., $\partial W / \partial V^l = 1$ and $\partial W / \partial V^h = \delta$) subject to the usual budget constraint and an incentive compatibility constraint (ICC) that the tax schedule has to be designed so that the high-ability consumers do not get a greater utility from mimicking the low-ability consumers than by selecting their own level of labor supply. In the general problem, there would be a similar condition for the low-ability consumer mimicking the high-ability consumer, however, in the "usual" case where the government wants to redistribute toward those with low ability, this constraint will not be binding.

The environmental part of the tax on D is given by

$$t_D{}^E = \phi\ (t_D{}^P - t_D \sum_i (\partial D^{\sim i} / \partial E) - (\mu V^{\wedge h}_M / \lambda)\ (MV^{\wedge h} - MV^l))$$

where now $\phi \equiv 1/ (\sum_i \partial D^{\sim i} / \partial E)$ and $\partial D^{\sim i} / \partial E$ denotes the compensated effect of the externality on the demand for D and $MV^{\wedge h}$ and $V^{\wedge h}_M$ denotes h's marginal valuation of the environment and marginal utility of income when mimicking type l (λ and μ are constants and represent the value of being able to relax the government's budget constraint and the ICC respectively).

Once again there is Sandmo additivity for the total tax on the dirty good, i.e., $t_D = t_D^{ICC} + t_D^E$, where t_D^{ICC} (the nonenvironmental part of the tax) reflects the effect of taxing D on the incentive compatibility constraint. An h type mimicking a type l will have the same income as a true l type but will work fewer hours. If D is complementary to leisure, then an h type mimicker will consume more of D than the true l type, which means the nonenvironmental part of the tax should be positive, and vice-versa if D and leisure are substitutes.

Substituting $t_D = t_D^{ICC} + t_D^E$ into the equation for t_D^E and rearranging gives

$$t_D^E = t_D^P - t_D^{ICC} \sum_i (\partial D^{\sim i} / \partial E) - (\mu \ V^{\wedge h}_M / \lambda)\ (MV^{\wedge h} - MV^l)$$

It is clear from this expression for t_D^E that if there is separability of preferences between consumption/leisure and the quality of the environment, then t_D^E is identical to the Pigouvian tax. The intuition for this is fairly straightforward. What prevents this tax system from achieving the first best is the need to avoid type h mimicking type l. If preferences over the environment are separable from those over leisure, the incentive compatibility constraint has no bearing on the setting of the environmental part of the tax on D since $\partial D^{\sim i} / \partial E = 0$ and $MV^{\wedge h} - MV^l$.

When environmental utility is not separable from other utility, the Pigouvian tax must be adjusted in two ways.

1. For the effect of environmental quality on tax revenue from the ICC part of the tax on D. This effect is similar to linear income tax cases except it is now the compensated demand for D that appears in the formula

2. The final term gives the effect of the incentive compatibility constraint. It is a function of the difference between the marginal valuation of an improved environment of an h type mimicking an l type and that of a true l type. Since we know that the mimicker has the same income but works fewer hours than the true l type, the sign of this term depends on the relationship between leisure and the environment. If environmental quality is a complement to leisure, then the mimicker values the environment more highly than the true type and this tends to reduce t_D^E since environmental improvements will increase the incentive to mimic.

From this we can see that t_D^E will be greater than/less than t_D^P depending on whether

$$t_D^{ICC} \sum_i (\partial D^{\sim i} / \partial E) - (\mu \ V^{\wedge h}_M / \lambda)\ (MV^{\wedge h} - MV^l) < \text{or} > 0$$

This expression will definitely be greater than zero if

- D and leisure are complements—so that $t_D^{ICC} > 0$
- D and E are complements (i.e., D and environmental quality are substitutes)—so that $\partial \tilde{D}^{i} / \partial E > 0$
- E and leisure are substitutes (i.e., environmental quality and leisure are complements)—so that $(\hat{MV}^{h} - MV^{l}) > 0$

These three conditions are sufficient for the environmental part of the tax on D to be less than the Pigouvian tax.

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