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Optimal Fiscal Policy and the Environment

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Abstract

The paper studies the setting of optimal fiscal policy in a second-best world with environmental externalities. The optimal second-best pollution tax is shown to lie below the first-best Pigovian tax, particularly if substitution between labor and polluting intermediate inputs is easy, the labor supply curve is more elastic, and preexisting taxes are large. The optimal level of public abatement is derived from the modified Samuelson rule and is larger if society cares more for the environment, public funds are inexpensive, and public abatement is relatively productive. The analysis also shows that the Samuelson rule should be revised if allowance is made for nonseparabilities in preferences.

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Contents

SUMMARY

The paper studies the setting of optimal fiscal policy in a world in which the government's tax system faces the dual task of internalizing environmental externalities and raising public funds to finance public spending on consumption and abatement. A simple general equilibrium model is employed in which pollution is caused as a by-product of production. Households derive utility from marketable goods, public consumption, and environmental quality.

The second-best optimal pollution tax is shown to lie below the first-best Pigovian tax, particularly if substitution between labor and polluting intermediate inputs is easy, the labor supply curve is more elastic, and preexisting taxes are large. Intuitively, an increase in environmental taxes exacerbates preexisting tax distortions, which makes internalizing environmental externalities more costly. The modified (or second-best) Samuelson rule is derived, which prescribes that more public funds will be devoted to public abatement if society has a stronger preference for environmental quality and public funds are less scarce.

The paper also shows that the Samuelson rule needs to be further revised if public goods (including the environment) directly affect labor supply. In this case, applying the standard Samuelson rule may yield an over- or undersupply of public goods depending on the nature of the interaction between public spending and the taxed activity.

I. INTRODUCTION

Environmental taxes have attracted increasing attention as a policy instrument to deal with pollution externalities. The standard Pigovian prescription entails charging the polluter a price for emissions which raises the private costs to the level of the social costs. Besides their ability to achieve environmental objectives, pollution taxes are also considered desirable because of their capacity to generate public revenue. In particular, governments can use these revenues to cut distortionary labor taxes thereby improving the environment and possibly enhancing the efficiency of the tax system as well. In the literature this is known as the "double dividend" hypothesis (cf. Terkla, 1984; Pearce, 1991; Bovenberg and de Mooij, 1994). Also, the revenues can be used to finance a rise in public spending on consumption or on projects aimed at abating environmental degradation.

Traditionally, it is argued that an extra unit of public expenditures on public goods is desirable as long as the sum (across households) of the marginal rates of substitution between public and private goods exceeds the relative resource costs or marginal rate of transformation. This welfare criterion as introduced by Samuelson (1954) assumes a first-best world in which the government has access to lump-sum taxes to finance public spending. However, when distortionary taxes are employed to finance public spending, additional indirect welfare costs should be added to the direct resource cost which brings us in the realms of a second-best world. A large literature exists on the optimal provision of public goods under distortionary taxation which was initiated by the pathbreaking articles of Stiglitz and Dasgupta (1971) and Atkinson and Stern (1974). To date little theoretical work has been done in the area of optimal environmental taxation and the optimal level of environmental expenditure in a second-best world. Notable exceptions are the work of Sandmo (1975), Lee and Misiolek (1986), Bovenberg and de Mooij (1994), Parry (1995), and Bovenberg and van der Ploeg (1994). The first four papers assume an exogenous level of public spending and therefore cannot study the optimal provision of public goods in conjunction with the optimal setting of environmental taxes. Moreover, Lee and Misiolek (1986) employ a partial equilibrium framework which is not suitable to investigate the effects of other preexisting tax rates on the setting of the optimal pollution tax rate.

The present paper analyzes the setting of optimal fiscal policy in a second-best world in which the tax system faces the dual task of internalizing externalities, on the one hand, and raising revenue to finance public goods, on the other hand. A simple general equilibrium framework with optimizing firms, households, and government is employed to take into account the interaction of pollution taxes with other preexisting taxes. The model builds on the work of Bovenberg and van der Ploeg (1994) and Bovenberg and de Mooij (1994) who consider a model in which the environmental externality is caused by polluting consumption goods. In the current model, however, polluting originates from output which is solely produced by labor. In an extension to the model allowance is made for substitution between non-polluting labor and polluting intermediate inputs (e.g., energy). It is shown that the optimal second-best environmental tax is below the first-best Pigovian tax.[2] The gap between the first-best and second-best tax widens if preexisting taxes are larger, the labor supply curve is more elastic, and substitution between labor and polluting intermediate inputs is easy. The modeling framework will also recognize that the objective of a clean environment may conflict with other goals of public policy. More concern with environmental damages will not go hand in hand with a higher level of employment suggesting that no "free lunches" can be reaped because environmental taxes may exacerbate rather than alleviate preexisting labor tax distortions.

To evaluate the desirability of additional public spending, governments usually conduct a cost-benefit analysis. As is widely accepted in the theoretical and empirical literature on cost-benefit analysis, the benefits of public expenditure and environmental quality enter the social welfare function in a separable fashion. This separability assumption implies that the utility from private goods can be analyzed apart from utility derived from public goods. In practice, this means that the cost of public funds can be subtracted from the estimated benefits of public projects[3] to derive the net benefit of a project. However, if public spending substitutes for private consumption (e.g., free of charge public health care will crowd out private health care)—as also studied in Wildasin (1984) and Mayshar (1991)—or if environmental quality is complementary to leisure (e.g., clean rivers encourage more recreational fishing) this simple procedure is no longer valid. It is shown in the paper that when the benefits of public goods enter the social welfare function in a nonseparable fashion, the standard Samuelson rule needs to be revised. The traditional concept of the marginal cost of public funds[4] may over- or understate the "true cost" of public goods provision depending on the assumptions made on the preference structure.

The rest of the paper is structured as follows. In Section II a simple general equilibrium model is developed in which pollution is assumed to be generated as a side-product of production. The government protects the environment by means of a pollution tax which is imposed on firms and spending on public abatement.[5] Optimal fiscal policy is determined in both a first-

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[2]Bovenberg and Goulder (1996) empirically determine the optimal carbon tax using a dynamic computable general equilibrium model for the U.S. economy. They find that optimal carbon taxes are far below the marginal environmental damages.

[3]See Hanley and Spash (1993) for an overview of various methods to estimate the monetary benefits of nonmarketed goods.

[4]This is the decline in utility associated with raising $1 of additional public revenues.

[5]Public abatement expenditures can be defined to include all those public spending activities aimed at the prevention, reduction, and elimination of pollution and nuisances that can have a harmful effect on the environment. For example, the cleaning-up of contaminated soil,

(continued...)

best world in which lump-sum taxes are available and in a second-best world where preexisting tax distortions are present. Section III extends the analysis to allow for nonseparabilities in preferences of households. Two cases are studied: (i) private and public goods are perfect substitutes, and (ii) leisure and environmental quality are complements. In Section IV the basic model is extended by adding a polluting intermediate input to analyze the effect of factor substitution on the setting of the optimal pollution tax rate. Section V concludes.

II. OPTIMAL FISCAL POLICY AND THE ENVIRONMENT

To study the optimal setting of fiscal policy, a simple general equilibrium model is developed in which pollution is generated as a side-product of production. In this framework the government supplies three public goods, viz., public consumption, public abatement, and the public good of the environment. This enables us to investigate what factors crucially affect the setting of optimal environmental levies, on the one hand, and the optimal level and composition of public spending on the other hand. In addition, the issue of whether more environmental concern can yield both improvements in environmental quality and employment is evaluated.

A. Analytical Framework

Consider a society which derives utility, Λ, from marketable goods (i.e., private consumption, C, and leisure, V), public consumption, G, and environmental quality, E. Social welfare is given by:[6]

$$\Lambda \equiv U(C,V) + \gamma_G H\Gamma(G) + \gamma_E HE,$$
$$U_C>0,\ U_{CC}\leq 0,\ U_V>0,\ U_{VV}\leq 0,\ \Gamma'>0,\ \Gamma''\leq 0, \tag{1}$$

where subscripts and primes denote partial derivatives and H denotes the number of households in the economy. The social weights given to public consumption and

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[5](...continued)
treatment of exhaust gases, and water purification treatment. This definition excludes activities in the area of natural resource protection, which is in line with the definition of "Pollution Abatement and Control Expenditures" as employed by the OECD (1993). In practice, public abatement outlays are very small—for OECD countries on average 0.6 percent of GDP in 1990—since polluters are required to pay for the environmental damages if they can be identified (the so-called Polluter-Pays Principle).

[6]Aggregate labor supply, L, is derived from N-V, where N is the total amount of time available to all households which can without loss of generality be normalized to unity.

environmental quality are denoted by γ_G and γ_E, respectively. The subutility index $U(.,.)$ denotes aggregate private utility and is assumed to be well-behaved and linearly homogeneous. Social welfare is strictly separable in private welfare, public consumption, and environmental quality implying that private utility is not affected by the provision of public goods (including the environment). This separability assumption is in line with most of the existing literature on revenue-neutral environmental tax reforms (see Bovenberg and de Mooij, 1994; and Bovenberg and van der Ploeg, 1994). It will be relaxed later.

Environmental quality is damaged by emissions, which are assumed to be linearly related to output, Y, but improves if the government devotes resources to the environment, A, so-called public abatement activities:

$$E = E_v - \beta Y + e(A), \quad e'(A)>0,\ e''(A) \leq 0, \tag{2}$$

where β is the (fixed) emission-output coefficient and E_v represents the "virgin state" of the environment which is obtained without pollution. In this so-called *flow* approach it is assumed that the environment can recover quite rapidly once the source of pollution is removed. However, it cannot allow for the gradual damaging effect of emissions on environmental quality over time (e.g., acid rain which causes trees to slowly die off). Public abatement activities are assumed to be independent of output and are subject to decreasing returns.[7]

Firms produce output according to a constant returns production function with labor, L, as the sole input. Accordingly, with labor productivity assumed to be unity, $Y=L$. Firms maximize profits, $\Pi \equiv PY-w_N L$, under perfect competition which implies that real wage costs, w_N/P, should be equal to labor productivity, where w_N denotes the nominal wage rate and P denotes the price of final output.

Consumers maximize utility subject to their budget constraint and the given level of public consumption and environmental quality. The household budget constraint dictates that households consume out of after-tax labor income, $P_C C=w_N(1-t)L-T$, where t is a labor income tax,[8] P_C is the price of final consumption, and T is a lump-sum tax. The first-order conditions yield $U_V/U_C=w_N(1-t)/P_C \equiv w$ which says that the marginal rate of substitution between leisure and private consumption should equal the after-tax real consumer wage. The nominal wage is chosen as the numeraire, that is, $w_N \equiv 1$.

To study the effect of changes in taxes on private behavior the model can be log linearized around an initial state. A tilde (~) denotes a relative change, except for $\tilde{t} \equiv dt/(1-t)$ and $\tilde{T} \equiv dT/Y$.

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[7]Public abatement is treated as current public expenditure and is of the end-of-pipe type since the production technology is assumed to be given. That is, pollution is abated by installing more scrubbers rather than using the factor inputs in a less polluting way.

[8]Without loss of generality this tax could have been imposed on the employer.

Log linearizing the first-order conditions, using the household budget constraint, yields expressions for the relative change in private consumption, labor supply, and indirect private utility:

$$\tilde{C} = \left[V(\sigma_{CV} - 1) + 1\right]\tilde{w} - L\tilde{T}/\omega, \tag{3}$$

$$\tilde{L} = V(\sigma_{CV} - 1)\tilde{w} + V\tilde{T}/\omega, \tag{4}$$

$$\tilde{M} = \left[\phi\sigma_{CV} - (\sigma_{CV} - 1)L\right]\tilde{w} - L\tilde{T}/\omega, \tag{5}$$

where $\omega \equiv P_C C/PY$ denotes the consumption share in output, σ_{CV} denotes the elasticity of substitution between private consumption and leisure, and $\phi \equiv M_C C/M$ is the share of private consumption in indirect private utility. By imposing $\sigma_{CV}>1$, so that $L_w>0$, an upward sloping labor supply curve is assumed. This means that the positive substitution effect in labor supply of a change in the after-tax real wage dominates the negative income effect. Employment is supply determined due to the assumption of an infinitely elastic labor demand curve. A rise in the labor income tax rate shifts the labor supply curve to the left thereby depressing employment and the after-tax real consumer wage. In this case employers can fully shift the burden of labor taxes to employees implying that after-tax real wages fall one-for-one with the increase in the labor tax rate, that is, $\tilde{w}=-\tilde{t}$. However, a rise in the lump-sum tax raises employment as households work harder to compensate for the loss in disposable income.

The government finances its spending on consumption and abatement in two ways: (i) by imposing a lump-sum tax on households, or (ii) by levying a proportional tax on labor which is partially motivated by environmental concerns. Note that in this case, the labor tax is equivalent to a tax on output since labor is the only factor of production. As a result, the government budget constraint amounts to $tL=P_G(G+A)$, where P_G denotes the resource costs of public spending. To close the model, goods market equilibrium requires that national income, Z, equals total economy-wide expenditure, that is, $Z=P_C C+P_G(G+A)$.

B. The Command Economy Outcome

As a benchmark, we can derive the first-best outcome that can be obtained in a world in which the social planner can directly allocate the available resources in a socially optimal way. The planner solves the following optimization problem:

$$\begin{aligned}\Phi \equiv\ & U(C,V) + \gamma_G H\Gamma(G) + \gamma_E H\left[E_v - \beta L + e(A)\right] \\ & + \lambda\left[Z - P_C C - P_G(G+A)\right],\end{aligned} \tag{6}$$

where $\lambda \equiv U_C/P_C$ denotes the social marginal utility of private consumption. From the first-order conditions for private consumption and public consumption we get Samuelson's (1954) rule:

$$\frac{\gamma_G H \Gamma'(G)}{U_C} = \frac{P_G}{P_C}. \tag{7}$$

The Samuelson rule says that the summed marginal rates of substitution between public consumption and private consumption should be equal to the marginal rate of transformation (or relative resource costs). This means that it is desirable to allocate additional units of resources to public consumption as long as it is less expensive than private consumption. Without loss of generality, the prices of private consumption, public consumption, and final output can be normalized to unity, that is, $P_C = P_G = P \equiv 1$.

By combining the first-order conditions for public consumption and public abatement the following efficiency condition can be obtained:

$$\frac{\gamma_G \Gamma'(G)}{\gamma_E} = e'(A). \tag{8}$$

Public abatement is optimally set if the marginal rate of substitution between public consumption and public abatement is equal to the marginal rate of transformation. The latter represents the improvement in environmental quality if one unit of public funds is directed away from public consumption toward public abatement. By writing (8) in relative changes, assuming a constant level of public expenditures,[9] we arrive at the following expression:

$$\left[\frac{\chi}{1-\chi}\sigma_G + \sigma_A\right]\tilde{A} = \tilde{\gamma}_E - \tilde{\gamma}_G, \tag{9}$$

where the productivity of public abatement and the elasticity of the marginal utility of public consumption are given by:

$$\sigma_A \equiv -\frac{e''(A)A}{e'(A)} > 0, \qquad \sigma_G \equiv -\frac{\Gamma''(G)G}{\Gamma'(G)} > 0, \tag{10}$$

where $\chi \equiv A/(A+G)$ is the share of public abatement in public revenues. It can be concluded that more public funds are devoted to public abatement (at the expense of public

[9]This assumption will be relaxed in the next section.

consumption)[10] if more priority is assigned to the environment ($\tilde{\gamma}_E$>0), particularly if the productivity of public abatement does not drop off rapidly (small σ_A), the marginal utility of public consumption does not decline much (small σ_G), and the share of public abatement in public spending is small.

The first-order conditions for private consumption and labor supply are given by:

$$\lambda = U_C = U_V + \gamma_E \beta H. \tag{11}$$

The social marginal utility of private consumption must equal the marginal benefits of leisure plus a term correcting for the environmental externality.

C. The Decentralized Market Outcome

This section will investigate under what conditions the first-best outcome can be obtained in a decentralized market economy. Generally, the first-best outcome is only sustainable in a market economy if the government has access to lump-sum taxes or transfers (i.e., t=0) to balance its budget. In this case, public revenue can be raised without creating any distortions.

Just like in the command economy, the government sets $\gamma_G H\Gamma'(G)/U_C$=1, where U_C now denotes the private marginal utility of consumption (or alternatively, the marginal utility of after-tax income). The optimal level of public consumption in the market economy is only equal to the first-best level if the government decides to fully internalize the environmental externality. The original Samuelson rule thus requires no distortions anywhere. Without government intervention firms receive a *virtual* pollution subsidy since they are free to pollute the environment. In that case, the decentralized market outcome implies too high a level of private *and* public consumption. In line with the recommendations made by Pigou (1947), the government should set the following tax to correct the externality:

$$\tau_p = \frac{\gamma_E \beta H}{U_C}. \tag{12}$$

The first-best Pigovian tax equals the sum of the marginal damages scaled by the marginal utility of after-tax income.[11] This fully internalizes the environmental externality but does not eliminate all pollution as this would require a zero level of economic activity. The Pigovian tax rate is high if the emission-output coefficient is large, the population is large, and society cares

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[10]The government can directly choose the level of spending on public consumption and public abatement. However, it can only indirectly influence the provision of the public good of the environment through the setting of the labor tax rate and the level of public abatement.

[11]Alternatively, the Pigovian tax rate could be expressed in terms of the marginal utility of leisure. This would yield the following expression: $\tau_p/(1-\tau_p)=\gamma_E\beta H/U_V$.

more for the environment. In a Pigovian world it is assumed that the revenues of the pollution tax are rebated to households in a lump-sum fashion. In the next section we will see that revenue from the pollution tax can be employed more productively by using it to finance the supply of public goods.

D. Optimal Fiscal Policy in a Second-Best World

Now we assume that the government faces a second-best world in which it cannot use lump-sum taxes (i.e., T=0) to balance its budget. As a result, it has to resort to a distortionary tax on labor (or equivalently, on output) to finance public spending (cf. Atkinson and Stern, 1974). Under these circumstances, allocating more public funds to the environment is more costly to the government. The tax system faces the dual task of, on the one hand, internalizing pollution externalities, and, on the other hand, raising revenues to finance public spending on consumption goods and the environment.

The second-best problem of the government is to choose public consumption, public abatement, and the tax rate in such a way to maximize social welfare. Solving the first-order conditions yields the *modified* (or second-best) Samuelson rule adjusted for environmental considerations:[12]

$$\frac{\gamma_G H \Gamma'(G)}{M_C} = \eta \equiv \frac{1}{1 - \left[\frac{t-p}{1-t}\right]\epsilon_w^s}, \tag{13}$$

where $\eta \equiv \mu / M_C$ is the marginal cost of public funds (MCPF), μ denotes the social marginal disutility of raising public revenue, $p \equiv \gamma_E H \beta / \mu$ is the *implicit* pollution tax,[13] and $\epsilon_w^s \equiv V(\sigma_{CV}-1)>0$ is the uncompensated after-tax wage elasticity of labor supply.[14] The MCPF is defined in terms of the reference private good and measures the marginal distortionary costs associated with raising public revenue. It is assumed that the size of the government (as measured by the public spending-output ratio) is sufficiently large for $t>p$ to be satisfied, but not too large to violate the no-Laffer curve condition, that is, $1-t(1+\epsilon_w^s)>0$. According to the modified

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[12]In deriving equation (13) use is made of Roy's identity which says that $L=m_w/M_C$.

[13]This tax is *implicit* since no separate pollution tax is distinguished in the model. It thus forms part of the labor tax.

[14]Harberger (1964) and Browning (1976) derive formulas for the MCPF that feature the *compensated* wage elasticity of labor supply. They maintain a constant level of public spending by means of a lump-sum rebate of labor tax revenue to households. The lump-sum rebate offsets any income effects so that only the pure substitution effect remains.

Samuelson rule the government should equate the rate of substitution between public consumption (or alternatively public abatement) and private consumption to the MCPF.

In the case of a preexisting tax on labor, the MCPF exceeds unity indicating that public projects are more expensive than private projects. Accordingly, public spending is lower than in a world in which lump-sum taxes are available. This result is consistent with the theoretical and empirical literature on the MCPF as surveyed in Ballard and Fullerton (1992). The MCPF is particularly large if the implicit pollution tax is small, the uncompensated wage elasticity of labor supply is large, and the preexisting labor tax is large. Intuitively, with a small implicit pollution tax the government receives less public funds in a nondistortionary fashion. A large uncompensated wage elasticity of labor supply and a high initial labor tax rate imply that a given rise in the labor tax rate leads to a large erosion of the tax base. The latter follows from the well-known notion that the deadweight loss of a tax increase rises with the square of the tax rate. Note that in the hypothetical case of $t=p$ or $\epsilon_w^s=0$ the MCPF is unity implying a first-best result. In the former case the pollution externality raises just enough public funds to finance public spending. Clearly, when the uncompensated labor supply curve is vertical, that is, $\epsilon_w^s=0$, taxation does not affect labor supply and thus does not induce any efficiency losses.[15]

Rewriting equation (13) shows the optimal second-best tax decomposed into the two tasks of the government's tax system:

$$t = \frac{1}{\Delta}\left[\frac{1}{\eta}\tau_p + \left(1-\frac{1}{\eta}\right)\frac{1}{\epsilon_w^s}\right], \quad \Delta \equiv 1 + \left(1-\frac{1}{\eta}\right)\frac{1}{\epsilon_w^s}>0, \tag{13'}$$

where τ_p denotes the Pigovian tax rate as obtained in a first-best setting. The second-best optimal tax is a weighted sum of the externality correcting tax (the first term between brackets on the right-hand side) and the revenue-raising objective or Ramsey term (second term on the right-hand side). The MCPF is used as a weighting factor (cf. Sandmo, 1975). According to Ramsey (1927) goods that are inelastic in supply should be taxed more heavily. As public funds become more valuable, the government puts less weight on internalizing environmental externalities and more on revenue raising. All public goods become more expensive including the environment. Note that the second-best pollution tax, $p\equiv\tau_p/\eta$, is less than the first-best Pigovian tax rate since the MCPF exceeds unity.[16] This is contrary to received wisdom in the

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[15]We refer here to the notion of distortionary taxes in the sense that the quantity of labor supplied is negatively affected by a higher labor tax rate.

[16]Bovenberg and van der Ploeg (1994) have made this claim in a general equilibrium model with a clean and a polluting consumption good. Fullerton (1997), however, has noted that Bovenberg and van der Ploeg's result is not as general as is suggested since it depends on the (continued...)

early literature (see Lee and Misiolek, 1986) which claimed that the optimal second-best pollution tax should exceed the Pigovian tax as long as increasing the pollution tax would generate public revenue.

The efficiency rule as described by equation (8) is unchanged in a second-best world because the trade-off between public consumption and abatement is not affected by the marginal cost of public funds. Alternatively, the optimal amount of public abatement follows from the counterpart of (13), $\gamma_E He'(A)/M_C = \eta$. Log-linearizing this expression yields the optimal change in public abatement:

$$\tilde{A} = \left[\tilde{\gamma}_E + \tilde{H} - \tilde{\mu}\right]/\sigma_A. \tag{14}$$

More public funds are devoted to abatement if society has a stronger preference for environmental quality and public funds are less scarce (as measured by a lower social marginal disutility of raising public revenue).

Assuming a simple linear function for the benefits derived from public goods, that is, $\Gamma(G) \equiv G$, we can log linearize equation (13) to obtain two schedules in the $(\tilde{\eta}, \tilde{t})$ space which are depicted in Figure 1:[17]

$$\tilde{\eta} = \tilde{\gamma}_G - (1-\phi)\tilde{t}, \tag{15}$$

$$\tilde{\eta} = \eta(1-p)\epsilon_w^s \tilde{t} - \frac{\tau_p}{1-t}\epsilon_w^s\left[\tilde{\gamma}_E - \tilde{\gamma}_G + \tilde{\beta}\right], \tag{16}$$

Log linearizing the left-hand side of (13) yields equation (15) which represents a downward sloping demand curve (D). Intuitively, a rise in the labor tax induces households to substitute from private consumption toward leisure. Accordingly, the marginal utility of private consumption rises which makes public consumption less urgent so that society is not willing to pay such a high MCPF. From the right-hand side of equation (13) we can derive (16) which is

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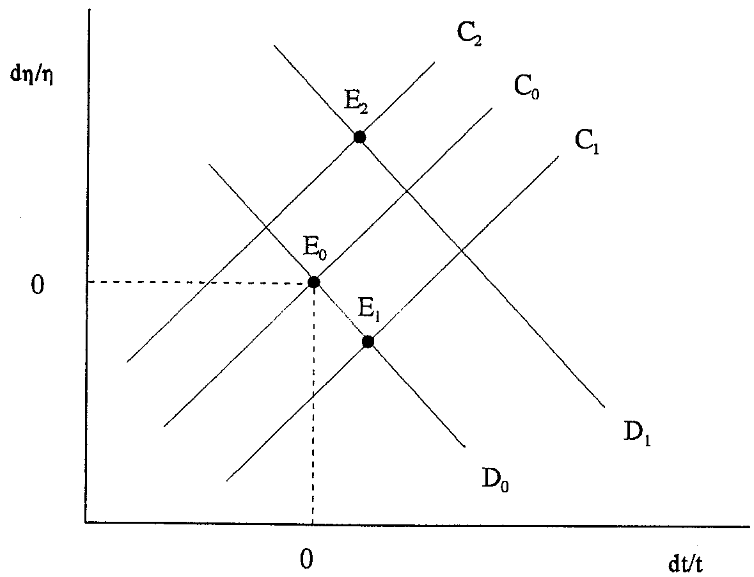
[16](...continued)
choice to set the tax on the clean commodity equal to zero. More correctly, they have proven that it should be the difference between the tax on the polluting and the clean commodity that is less than the Pigovian tax rate. In a model with only one tax rate this problem does not occur.

[17]Log linearizing the right-hand side of (13) yields $\tilde{\eta} = \tilde{\gamma}_G - \tilde{M}_C$, where $\tilde{M}_C = -(1-\phi)\tilde{w}$ and $\tilde{w} = -\tilde{t}$. The second expression follows from taking the total differential of private utility and log linearizing $M = M_C C + M_V V$ (which follows from Euler's rule). This yields $\phi \tilde{M}_C = -(1-\phi)\tilde{M}_V$, where use is made of $\tilde{M}_V - \tilde{M}_C = \tilde{w}$, which follows from the first-order condition of the household problem.

Figure 1. Optimal Environmental Taxes and the Marginal Cost of Public Funds in a Second-Best World



Key: A greater weight to environmental quality shifts the equilibrium from E_0 to E_1, thereby lowering the marginal cost of public funds and raising the optimal tax rate. A greater preference for public consumption goods shifts the equilibrium from E_0 to E_2 thereby raising the marginal cost of funds.

an upward sloping cost curve (C). The positive slope is due to the negative effect of an increase in the tax rate on the labor tax base which makes revenue raising more costly.

The intersection of both curves determines the optimal changes in the second-best tax and the associated equilibrium change in the MCPF. Solving (15)–(16) for the change in the tax rate as a function of changes in the parameters γ_E, γ_G, and β yields

$$\tilde{t} = \frac{\tau_p \epsilon_w^s}{\Delta_\eta (1-t)} \left[\tilde{\gamma}_E + \tilde{\beta} \right] + \frac{1}{\Delta_\eta} \left[\frac{\tau_p \epsilon_w^s}{1-t} - 1 \right] \tilde{\gamma}_G, \tag{17}$$

where $\Delta_\eta \equiv [\eta(1-p)\epsilon_w^s + 1 - \phi] > 0$. Greener social preferences ($\tilde{\gamma}_E > 0$) shift the cost curve to the right (from C_0 to C_1) thereby raising the optimal (balanced-budget) level of the optimal pollution tax rate and depressing the MCPF. The shift is particularly large if the initial pollution externality is substantial and the uncompensated wage elasticity of labor supply is high. As a result, environmental quality improves significantly but employment unambiguously deteriorates. In this respect there is a trade-off between the goal of a cleaner environment and the macroeconomic objective of more employment.[18] A larger emission-output coefficient also shifts the cost curve to the right because of the larger environmental externality that needs to be internalized. If society cares more about the level of public consumption ($\tilde{\gamma}_G > 0$), however, the demand curve shifts up (from D_0 to D_1) since society is willing to pay a higher MCPF. In addition, the cost curve shifts upward because sustaining the larger size of the public sector becomes more costly. The effect on the optimal tax rate is ambiguous but is likely to be positive if preexisting taxes are high.

III. OPTIMAL FISCAL POLICY WITH NONSEPARABLE PREFERENCES

In the previous section it was assumed that public spending on the environment and consumption enter the social welfare function in a separable way. This means that the level of public goods supply does not affect the consumption-leisure decision[19] which allows the value

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[18]However, it should be noted that both goals of public policy may be compatible in a world in which the burden of environmental taxation can be shifted toward agents outside the labor market. Ligthart and van der Ploeg (1996) show in an optimal tax model, in which output is produced with labor, polluting natural resources (e.g., energy), and a fixed factor, that capital owners bear a large part of the environmental tax burden if substitution between labor and natural resources is easy and the fixed factor does not substitute easily with the other factors of production.

[19]In the case of *strict* (or additive) separability (as is assumed in equation (1)), public goods do

(continued...)

of the benefits of public projects to be calculated independently of the costs in a cost-benefit analysis. However, the level of public goods provision is likely to affect household decisions in which case the costs and benefits of public spending are difficult to disentangle. This section shows that with feedback effects the standard first-best Samuelsonian condition does not need to be satisfied even when the government has access to lump-sum taxes. In addition, the optimal second-best level of public goods is likely to lie below the level associated with the standard second-best Samuelson rule. To illustrate these claims two special cases will be studied: (i) public and private consumption are perfect substitutes, and (ii) environmental quality and leisure are complements. Wildasin (1984) was the first one to raise the issue that an increase in public goods provision may increase (decrease) the tax base when private and public goods are complements (substitutes) thereby over (under)stating the "true" marginal cost of public goods. Mayshar (1991) extends Wildasin's analysis to allow for progressive taxation, but studies tax reform rather than optimal taxation. Both studies assume a general utility function of the form $U(C,V,G)$ and do not consider environmental externalities.

A. Public and Private Consumption as Perfect Substitutes

Bailey (1971) was the first to propose that publicly provided goods may substitute for private consumption. For example, a household which receives free of charge health care by the government will buy less private health care. In view of this, private welfare now amounts to $U(C_E,V)$, where effective consumption, C_E, can be defined as the weighted sum of private and public consumption:

$$C_E \equiv C + \theta G, \quad \theta>0, \tag{18}$$

where the parameter θ is the (constant) marginal rate of substitution between private and public consumption, which measures the degree of direct "crowding out" of private by public consumption. Publicly provided consumptive goods directly crowd out private goods (if $\theta>0$) since consumers receive "virtual" income in the form of the public goods. Kormendi (1983) and Aschauer (1985) report estimates for θ between 0.23 and 0.42 for the United States and Ahmed (1986) finds a value of 0.4 for the United Kingdom, that is, well below unity. This indicates weak crowding out in which case there is typically less than one-for-one replacement of private by public consumption.[20] Karras (1994), however, argues that private and public

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[19](...continued)
not affect the level of private welfare either. This was the case considered by Atkinson and Stern (1974).

[20]In a world where the government employs lump-sum taxes to balance its budget (i.e., $G=HT_H$, where T_H is a lump-sum tax levied on the representative household) the consumer effectively pays T_H to finance public goods. However, the household receives αG in the form of public goods. In the aggregate, the household sector thus receives a *net virtual income*
(continued...)

consumption are both very heterogeneous aggregates. Some categories of government spending may be close substitutes for private spending (e.g., free school lunches) whereas others (e.g., public transportation) are more likely to be complements.[21] In his empirical study he observes a complementary relationship in the aggregate for 24 out of a sample of 30 countries (not including the United States). In this case, θ takes on negative values. The empirical evidence thus tends to suggest that the results are country specific and dependent on the type of commodity under consideration.

Solving the household problem yields the demand for private consumption and labor supply:

$$C = c(w, G, T), \quad L = l(w, G, T), \quad c_G<0, \quad l_G<0, \tag{19}$$

where the signs of the partial derivatives of the other variables are as in equations (3)-(5). From (19) it can be seen that changes in the level of provision of public goods also directly affects the household's labor supply decision. If private and public spending are substitutes, as is observed for the United States, the income effect of a higher level of public consumption encourages households to work less, $l_G<0$. However, changes in the level of public consumption do not produce a direct substitution effect in labor supply, only indirectly through the higher taxes needed to finance the spending impulse.

As in Heijdra and Ligthart (1997) the concept of the *net* (or effective) marginal cost of public funds (NCF) is employed in this section to measure the costs of public spending net of the benefits/costs arising from nonseparable public consumption.[22] In their model, public spending gives rise to both a private and public good aspect. For example, an individual may derive utility from Medicaid but also from the fact that other households receive Medicaid as well. The public component of public spending in social welfare equals the separable benefits whereas the private component represents the nonseparable benefits. Note that, theoretically it is unclear what part of the welfare improvement should be credited to the benefit side and

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[20](...continued)
transfer of $-(1-\alpha)G$. If $0<\alpha<1$, consumers effectively have to pay more through direct lump-sum taxes than the value of the public goods they receive. However, if α equals unity, households receive a zero net virtual income transfer implying that they are indifferent between private and public goods from a welfare point of view.

[21]Private consumption and public consumption are substitutes (complements) if the marginal utility of one declines (increases) when the quantity of the other is increased. In the present case we have $U'>0$ and $U''<0$ and $\partial(\partial U/\partial C)/\partial G=\theta U''$ which is positive (negative) if $\theta>0$ (<0).

[22] Note that Heijdra and Ligthart (1997) do not consider environmental externalities. However, they mainly focus on another distortion caused by imperfect competition in the goods market.

what part to be subtracted from the cost side. Typically, the feedback effects affect utility directly as well as indirectly through changes in government revenue induced by changes in the labor tax base. Mayshar (1991) argues in an analytical exposition on the MCPF that the feedback effects should be attributed to the benefit side since they are not caused by a change in tax policy. However, in practice, governments often rely on cost-effectiveness studies to evaluate public projects in which case it may make sense to include the feedback effects on the cost side to be able to capture at least its impact on the tax base.

The optimal government policy follows from maximizing the social welfare subject to the government budget constraint. Under lump-sum taxation (T>0) and without environmental externalities, the marginal benefits of a unit of public consumption exceed the benefits as derived under the standard Samuelsonian rule (see equation (7)). The true cost of public funds is given by NCF=1-θ<1 where the *gross* MCPF (as derived under separable public spending) is unity. This is because part of government spending acts like an "in kind" income transfer which partially offsets the rise in lump-sum taxes needed to finance the increase in public spending. Accordingly, compared with the standard case of separable public spending, direct crowding out raises the optimal level of public spending on both consumption and abatement. Allowing for environmental externalities adds a second term to the expression which reduces the NCF even further:

$$\frac{\gamma_G H \Gamma'(G)}{U_C} = \text{NCF} = 1 - \theta - \tau_p \epsilon_{LG}/\omega_G, \qquad \epsilon_{LG} \equiv -\frac{\partial L}{\partial G}\frac{G}{L} > 0, \tag{20}$$

where $\omega_G \equiv G/Y$ denotes the output share of public consumption and ϵ_{LG} denotes the elasticity of labor supply with respect to public consumption. Spending on public consumption reduces labor supply which reduces emissions and thus gives rise to environmental benefits. Consequently, the net MCPF is further reduced below unity yielding a higher level of public spending than under the standard first-best Samuelson rule. The composition of the optimal spending portfolio is shifted toward more public consumption than in the separable case since public consumption yields additional private benefits (the second term on the right-hand side of (20)) and environmental benefits through a lower level of employment (the third term on the right-hand side of (20)).

Without lump-sum taxation public spending may also yield additional costs because of the effect of the nonseparable component of public spending on the tax base. Combining the government's first-order conditions, taking into account any feedback effects, yields:

$$\text{NCF} = \eta\left(1 + \frac{\epsilon_{LG}}{1-\chi}\right) - \theta - \tau_p \epsilon_{LG}/\omega_G, \tag{21}$$

where η is the gross (or standard) MCPF which is given by equation (13). The term between brackets is positive under the current assumptions since it adds to the costs of raising public revenues. The "in-kind" transfer associated with public spending makes households feel wealthier which discourages labor supply. Hence, the labor tax base erodes creating a larger deadweight burden of taxation, particularly if initially a lot of public abatement is undertaken. However, the supply of the public good of the environment becomes cheaper as feedback effects contribute positively to environmental quality. Whether the standard MCPF understates (or overstates) the true cost of public funds cannot a priori be determined. If environmental externalities are negligible, however, the true cost of public funds is likely to exceed the gross MCPF. If private and public consumption are complements (i.e., $\theta<0$ and $\epsilon_{LG}<0$)[23] a NCF less than unity may be attained, even under proportional labor taxes, if: environmental externalities are not important; there is not much public abatement; and public consumption "crowds in" a lot of private consumption. In this case the positive feedback effect on labor supply resulting from public spending may offset the decline in labor supply due to higher income taxation. Accordingly, public goods are overprovided relative to the first-best Samuelson rule.

B. Environmental Quality and Leisure as Complements

In the second special case environmental quality is complementary to leisure—a cleaner environment encourages households to enjoy more leisure thereby decreasing economic activity. For example, clean rivers encourage more recreational fishing.[24] Greenley, Walsh, and Young (1981) have estimated that the demand for water-based recreation in the Colorado River Basin increases when water quality improves. The estimated recreation-derived benefit from water quality improvements per person averaged US$79 annually.[25] Labor supply of households may then be negatively affected by the quality of the environment as is expressed by $L=l(w,E,T)$, with $l_E<0$. Social welfare can be written as: $\Lambda \equiv M(w,E,T)+\gamma_G H\Gamma(G)+\gamma_E HE$. A rise in environmental quality raises social welfare due to the separable public component, but depresses social welfare through a fall in private welfare, $M_E<0$. From the government's optimization program we can derive the net cost of public funds for abatement expenditures:

[23]Without environmental externalities and leisure weakly separable from a Cobb-Douglas subutility function of private and public consumption the optimal level of public goods provision exactly matches the one under the first-best Samuelson rule.

[24]A cleaner environment may also induce people to become more productive causing an upward shift in the labor demand curve. In this section we only focus on the effect of changes in environmental quality on the supply of labor.

[25]These studies do not control for the possible negative effect of the increase in time assigned to recreational fishing on the demand for other recreational activities.

$$NCF = \frac{\gamma_E H e'(A)}{U_C} = 1 + \frac{(-M_E)e'(A)}{U_C} - \beta\frac{\epsilon_{LE}}{\omega_E}, \quad \epsilon_{LE} \equiv -\frac{\partial L}{\partial E}\frac{E}{L} > 0, \tag{22a}$$

and the NCF for public consumption is given by:

$$NCF = \frac{\gamma_G H\Gamma'(G)}{U_C}, \tag{22b}$$

where $\omega_E \equiv E/Y$ denotes the output share of environmental quality and ϵ_{LE} is the elasticity of labor supply with respect to environmental quality. If the government undertakes public abatement, environmental quality improves which induces consumers to spend their time in a more environmental friendly way (the last term on the right-hand side of (22a)). This makes public abatement less expensive, particularly if the environment is heavily polluted (i.e., ω_E is small) and labor supply is relatively elastic (i.e., ϵ_{LE} is large). However, the reduction in labor supply induced by the higher level of environmental quality leads to a fall in private welfare and a higher NCF (the second term on the right-hand side of (22a)). In this setting the optimal provision of public abatement may be below the first-best level if the emission-output coefficient is small and the labor-environment elasticity ϵ_{LE} is small.

When public goods are financed by distortionary labor taxes, greener preferences increase the distortionary costs of pollution taxation through two effects that discourage labor supply: (i) the reduction in the after-tax wage, and (ii) the improvement in environmental quality (see the second term on the right-hand side of (24)). Consequently, the NCF is larger than the MCPF without any feedback effects and the optimal level of public spending is thus below the level obtained with separable environmental benefits:

$$L - \frac{1}{\lambda}\left[(-M_E) + \gamma_E H\right]\beta\frac{\mathrm{d}L}{\mathrm{d}t} = NCF\left[L + t\frac{\mathrm{d}L}{\mathrm{d}t}\right], \tag{23}$$

where the change in labor supply can be decomposed in:

$$\frac{\mathrm{d}L}{\mathrm{d}t} = \frac{\partial L}{\partial t} + \frac{\partial L}{\partial E}\frac{\mathrm{d}E}{\mathrm{d}t}. \tag{24}$$

Equation (23) can be rewritten to yield:

$$NCF = \frac{1}{1 - \left(\frac{t - p_E}{1 - t}\right)\left[\epsilon_w^s + \epsilon_{LE}\psi_E\right]}, \tag{25}$$

$$p_E \equiv \frac{\left(-M_E + \gamma_E H\right)\beta}{\mu}, \quad \psi_E \equiv \frac{\mathrm{d}E}{\mathrm{d}t}\frac{1-t}{E} > 0, \tag{26}$$

where p_E denotes the effective second-best pollution externality and ψ_E is the elasticity of environmental quality with respect to the pollution tax.

IV. OPTIMAL FISCAL POLICY WITH FACTOR INPUT SUBSTITUTION

This section extends the basic model of the second section by adding a polluting intermediate good (e.g., fossil fuels) which is used as input in the production of final output. This allows us to study the role of substitution between polluting energy and clean labor on the setting of optimal energy and labor taxes. For ease of exposition, public goods (including the public good of the environment) are assumed to be separable from private goods.

A. Firm and Consumer Behavior

Final output is produced by firms under constant returns to scale according to the following production function:

$$Y = \mathrm{F}(L_N, Z), \tag{27}$$

where F(.,.) exhibits the standard neoclassical properties, L_N denotes clean labor, and Z is a polluting intermediate input. Firms producing final goods maximize profits (π_Y) under perfect competition:

$$\pi_Y = pF(L_N, Z) - w_N L_N - q_Z(1 + t_Z)Z, \tag{28}$$

where p is the price of final output, q_Z the supply price of the intermediate good, and t_Z is a tax on energy use. The first-order conditions imply that the marginal productivity of labor and energy should equal the production cost of these factors:

$$p\frac{\partial F}{\partial L_N} = w_N, \quad p\frac{\partial F}{\partial Z} = q_Z(1 + t_Z). \tag{29}$$

Firms in the intermediate goods sector use labor as the sole input, L_Z, to produce energy according to a constant returns to scale technology. The profit function of firms producing intermediate goods is as follows, $\pi_Z \equiv (q_Z - w_N)L_Z$. From the first-order condition it follows that $q_Z = w_N$ which can without loss of generality be set to $q_Z = w_N \equiv 1$.

Consumers maximize private utility subject to their budget constraint, $pC=(1-t_L)L$, where t_L is a labor income tax. This yields expressions for private consumption, labor supply, and indirect private utility:

$$C = c(p, t_L), \quad L = l(p, t_L), \quad M = m(p, t_L). \tag{30}$$

The general equilibrium increase in the price of final output resulting from an incremental increase in the energy tax is defined as:

$$\tilde{p} = \omega_E \tilde{t}_E, \quad \omega_E \equiv \frac{(1+t_E)E}{pY} \tag{31}$$

Use of fossil fuels gives rise to emissions which cannot be abated through scrubbers or filters. As a result, a linear relationship between emissions and output is assumed. Environmental quality thus amounts to $E=E_V-\beta Z$. Goods market equilibrium implies that $Y=C+G$. Labor is fully mobile between the two sectors resulting in a common wage for both sectors. Labor market equilibrium requires that $L=L_N+L_Z$.

B. The Government's Second-Best Problem

The government maximizes social welfare, $M(p(t_Z),t_L)+\gamma_G H\Gamma(G)+\gamma_E HE$, subject to its budget constraint $G=t_L L+t_Z Z$. For ease of exposition, the benefits of public goods enter the social welfare function in a separable fashion. From the first-order condition for public consumption we can derive the modified Samuelson rule:

$$\frac{\gamma_G H\Gamma'(G)}{U_C} = \frac{u}{\lambda}. \tag{32}$$

The first-order conditions with respect to the labor tax and the pollution tax yield:

$$\frac{\mu}{\lambda} = \frac{1}{1 - \left(\frac{t_Z - p}{1 - t_L}\right)\epsilon_{ZL}s - \frac{t_L}{1 - t_L}\epsilon_{LL}} = \frac{1 - t_L}{1 - t_L - \left(\frac{t_Z - p}{1 + t_Z}\right)\epsilon_{ZZ} - \frac{t_L}{1 + t_Z}\epsilon_{LZ}s}, \tag{33}$$

where the ϵ_{ij} denotes the elasticity of demand for factor $i(=L,Z)$ with respect to the net factor price j. The respective factor demand elasticities are defined as follows:

$$\begin{aligned} \epsilon_{ZZ} &\equiv \epsilon_{ZL}\omega_Z + (1-s)\sigma_{LZ} > 0, \\ \epsilon_{ZL} &= \epsilon_{LL} \equiv V(\sigma_{CV} - 1) > 0, \\ \epsilon_{LZ} &\equiv \epsilon_{LL}\omega_Z > 0, \end{aligned} \tag{34}$$

and where σ_{LZ} denotes the substitution elasticity between polluting intermediate goods and labor while $s \equiv L_Z/L$ denotes the share of labor employed in the energy sector. It is assumed that t_Z and t_L are sufficiently small to yield an outcome on the correct (or upward-sloping) section of the Laffer curve. The second-best virtual pollution subsidy is defined as before:

$$p \equiv \frac{\gamma_E H \beta}{\mu} = \frac{\tau_p}{\eta} < \tau_p. \tag{35}$$

Equation (33) shows that the MCPF is large if the initial taxes on labor and energy are large, the share of labor in the intermediate goods sector is large, and the energy demand and labor demand elasticities are large. The energy demand elasticity with respect to the energy tax is particularly large if households can easily substitute between private consumption and leisure, the share of energy in national income is large, and the substitution elasticity between labor and energy is large. Even if the second-best energy tax equalizes the virtual pollution subsidy, that is, $t_Z = p$, the MCPF exceeds unity on account of the *tax-interaction effect*. This is the additional resource costs associated with the reduction in labor supply caused by the effect of higher energy prices on the price of final output which reduces the after-tax real wage. This can also be shown by totally differentiating the social welfare function, substituting the first-order conditions of households and firms, and setting the resulting expression equal to zero to derive the optimal energy tax as a function of the preexisting labor tax:

$$t_Z = \tau_p - t_L \left(1 + \frac{dL_N}{dL_Z} \right), \tag{36}$$

where $dL_N/dL_Z>0$ on account of the properties of the production technology which prescribes both factor inputs to be cooperative. Without a preexisting tax on nonpolluting labor in production there is no tax interaction effect which implies that the optimal energy tax equals the first-best Pigovian level. In the presence of a preexisting labor tax, the optimal energy tax depends negatively on the degree of substitution between clean and polluting labor and the size of the preexisting labor tax.

V. CONCLUSIONS

This paper has developed a general equilibrium model to study the setting of optimal fiscal policy in a world in which the tax system faces the dual task of internalizing production-related environmental externalities and raising public funds to finance public spending. In particular, attention is focused on the interaction of environmentally motivated taxes with other preexisting taxes.

It is shown that the second-best optimal Pigovian tax lies below the first-best Pigovian tax because interactions with preexisting tax distortions exacerbate the overall efficiency costs of an incremental increase in the pollution tax. The wedge between the first-best and second-best pollution tax is particularly large if substitution between labor and polluting intermediate goods is easy, the labor supply curve is more elastic, and the preexisting tax on labor is large. If public funds become more expensive (as indicated by a higher marginal cost of public funds) the tax system focuses more on revenue raising and less on internalizing environmental externalities. In addition, it is shown that more public funds will be devoted to public abatement if a greater priority is assigned to the environment with incremental abatement expenditures being greater if the productivity of public abatement does not taper off rapidly, few resources have been allocated to abatement already, and the costs of raising public funds are small. A shift toward greener preferences is shown to raise the optimal second-best pollution tax which depresses the after-tax real wage and discourages labor supply. Accordingly, a cleaner environment cannot go hand in hand with more employment.

In an extension to the basic model it is argued that a welfare evaluation of additional government spending should take into account the indirect (or feedback) effect of government spending on the demand for private goods. The standard first-best Samuelson rule—which says that the summed marginal rates of substitution between public and private consumption should equal unity—needs to be revised when allowance is made for nonseparabilities in preferences. When private and public goods are close substitutes and lump-sum taxes are available, a higher optimal level of public goods results than under separable public spending because consumers receive an "in-kind" transfer of resources which partially offsets the rise in lump-sum taxes. With distortionary taxes, public goods are likely to be underprovided relative to the level prescribed by the second-best Samuelson rule. This is also the case when a cleaner environment induces people to consume more leisure. The analysis implies that the marginal cost of public funds not only depends on the level of taxation but also on the nature of the specific public project under consideration and consumers' preferences. No general statements can be made on whether public goods provision is lower in a second-best world than in a first-best world.

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