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BRIDGING THE TAX-EXPENDITURE GAP: GREEN TAXES AND THE MARGINAL COST OF FUNDS

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Abstract

The marginal cost of public funds is usually seen as a number greater than one, reflecting the efficiency cost of distortionary taxes. But economic intuition suggests that since green taxes are efficiency-enhancing the MCF with such taxes will be less than one. The paper demonstrates that this intuition is not necessarily true, even when a green tax is the sole source of funds. The analysis also considers the MCF with a proportional income tax, given the presence of green taxes. It compares the optimization approach to the MCF with that of a balanced budget reform and shows that they lead to equivalent results.

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1. Introduction.

On several occasions Richard Musgrave has lamented the tendency in the theory of public finance to analyze questions of taxation and of the supply of public goods[1] in separate compartments. Although this practice can often be justified in terms of analytical tractability, it is true that a joint perspective on taxes and public expenditure is sometimes very important. In the recent literature this point has been emphasized in numerous studies of the concept of the marginal cost of (public) funds, or the MCF for short. The basic idea in this literature is that when public goods are financed by distortionary taxes, the efficiency costs that this entails should, in a cost-benefit analysis of public projects, be reflected in a multiplicative adjustment of the marginal social cost of increased supply. If public goods supply could have been financed by lump sum taxes, an increased supply involving a cost of 1 million euros and benefits of 1.2 million euros should definitely be carried out. But if each euro of tax revenue involves 0.3 euros of tax efficiency cost, then the MCF is 1.3 and the social cost should be computed as 1.3 times the direct resource cost. With a social cost of 1.3 million euros the proposed increase in public goods supply no longer passes the cost-benefit test, which can be written more generally as

marginal social benefit ≥ MCF x marginal social cost.

Thus, the concept of the marginal cost of public funds is the modern theory's response to Musgrave's critique. Its origin lies in the tax side of the public budget, and its application is to the determination of the expenditure side.

Like a number of other fundamental ideas in public finance, this one can be traced back to Pigou (1928). It re-entered the literature through the theory of optimal taxation, notably in a famous article by Atkinson and Stern (1974), although the MCF terminology was apparently introduced by Browning (1976). More recent contributions include Wildasin (1984), Mayshar (1991), Ballard and Fullerton (1992) and Håkonsen (1998). While most analyses of the MCF interpret it as a pure measure

[1] Or, more generally, publicly provided goods. These might – and indeed do – also comprise private goods in areas like health and education.

of inefficiency, some authors, like Wilson (1991), Dahlby (1998) and Sandmo (1998), have argued that the MCF should also incorporate a measure of the possible distributional gains from distortionary taxes. The basic argument for this is that taxes are distortionary precisely because one wants to achieve some distributional objective; hence the MCF should reflect the redistributional gain as well as the efficiency loss.

Underlying most of this literature is the crucial assumption that when lump sum taxes are not available, taxes used to finance the supply of public goods must be distortionary. But this is not necessarily the case. In the case of commodities or factors of production generating negative external effects, we know that the imposition of a tax reflecting the difference between marginal social and private cost (or between marginal private and social benefit) does not create any inefficiency; on the contrary, it leads to an efficiency gain. This insight has recently given rise to a large number of analyses of the so-called double dividend from a green tax reform, in which one studies the substitution of green or Pigouvian taxes[2] for standard distortionary taxes, assuming that government revenue is to be held constant. That the existence of a double dividend turns out not to be so obvious as might be suggested by partial equilibrium analysis comes essentially from the theoretical ambiguity of the direction of the cross-price effects between markets, an aspect not captured in the partial equilibrium approach[3].

The definition of the double dividend with constant tax revenue as the point of reference is, however, not the only one possible. If one believes that a distortionary tax system keeps the supply of public goods at an inefficiently low level, one way in which to reap the benefits of a less distortionary system would be to expand public expenditure, seeing that the MCF is now lower than it used to be. This idea has also a considerable appeal to economic intuition. In fact, partial equilibrium analysis would suggest that if increased public expenditure could be financed by Pigouvian or green taxes, the MCF should be *less than one*, since there is now an efficiency *gain* from tax finance which should be subtracted from the direct resource cost. But experience from

[2] Thus, the present paper can be seen as utilizing and combining two of Pigou's important contributions to the public economics literature, the possibility of efficiency-improving environmental taxes and the link between tax distortions and public goods supply. The idea of what we now refer to as Pigouvian taxes was first introduced in Pigou (1920); see in particular p. 99 of the 4th Edition (1932).

following the double dividend debate should warn us that there may be complications ahead and that a more general analysis is called for.

Among the contributions that already address this or related questions from a theoretical angle, van der Ploeg and Bovenberg (1994) and Kaplow (1996), are particularly noteworthy. van der Ploeg and Bovenberg study the effects of varying environmental preferences on the optimal supply of public goods, but they do not discuss the role of environmental taxes in determining the MCF. Kaplow's main concern is to study the role of optimal non-linear income taxation; under special assumptions about preferences he shows that we should think of the MCF in first-best terms[4]. The articles by Ballard and Medema (1993) and Brendemoen and Vennemo (1996) use computable general equilibrium models to study alternative sources of finance for public projects and find that the MCF for environmental taxes are much lower than for traditional taxes, sometimes indeed considerably below unity.

2. **Individual behaviour and the first best allocation.**

A desire for redistribution is essential for understanding why existing tax systems are distortionary. The efficiency loss from distortionary taxes therefore has to be balanced against redistributional gains, and to focus solely on the loss side, as one does in most of the literature on the marginal cost of funds, may therefore be misleading. However, in the interests of analytical simplicity, this is nevertheless what we shall do in the following, keeping in mind that distributional concerns can relatively easily be added on to the model, e.g. in the way in which it has been done in Sandmo (1998). Hence it is assumed that all n consumers are alike, and that the representative consumer's utility function can be written as

$$U = U(y, x, l, z, e), \qquad (1)$$

[3] For a more detailed analysis see Sandmo (2000, ch. 6) and the review of the literature by Bovenberg (1999).
[4] This is closely related to an earlier result in an important paper by Christiansen (1981).

where y and x are the quantities of two consumer goods, l is leisure, z is the supply of a public good and e is environmental pollution. U is increasing in the first four arguments and decreasing in the fifth. Environmental pollution is generated by the aggregate consumption of the x-good, so that $e = nx$. Labour supply is denoted by h, with $h + l = T$, which is the time endowment.

Each consumer maximizes his utility, taking the supply of public goods and the amount of environmental pollution as given, subject to the budget constraint

$$y + Px = w(1-t)h + a. \quad (2)$$

The y-good is the *numéraire*, while the consumer price of the x-good is $P = p + \tau$, where p is the producer price and τ is the tax rate. Labour income is subject to tax at the rate t. a is any exogenous income that the consumer might have; if $a<0$, it is a lump sum tax.

Utility maximization leads to the first order conditions

$$U_l / U_y = w(1-t), \quad (3)$$

$$U_x / U_y = P. \quad (4)$$

This gives rise to a supply function for labour

$$h = h(w(1-t), P, a, z, e), \quad (5)$$

and demand functions for the two consumer goods. In particular, the demand function for the x-good or "dirty good" is

$$x = x(w(1-t), P, a, z, e). \quad (6)$$

We assume that the dirty good is normal ($\partial x/\partial a>0$), implying that demand is a decreasing function of price ($\partial x/\partial P<0$).

Note the dependence of these functions on the state of the environment, *e*. While this is an exogeneous variable from the point of view of each single individual[5], changes in prices, taxes and public goods supply will in the aggregate affect individual behaviour through their effects on *e* and the feedback effects on labour supply and commodity demands. Many writers have chosen to neglect these feedback effects; the case in which there is a rigorous justification for it is of course where the utility function is weakly separable between the state of the environment and other goods, so that

$$U = U(\varphi(y, x, l, z), e), \qquad (1')$$

Separability is hardly a realistic assumption, and for a number of environmental problems, such as traffic congestion, non-separability and feedback effects are obviously very important. Nevertheless, it will be adopted in what follows, basically because it simplifies the analysis without distorting the qualitative conclusions that can be drawn from it.

Optimizing behaviour also implies the indirect utility function

$$V = V(w(1-t), P, a, z, e), \qquad (7)$$

with the Roy conditions

$$V_t = -\lambda wh; \;\; V_P = -\lambda x; \;\; V_a = \lambda. \qquad (8)$$

We now turn from individual behaviour to social welfare maximization. With all individuals being alike, a natural choice for a social welfare function is the utilitarian

[5] This may require a comment in view of the assumption that all individuals are identical. The essential part of the assumption is that each consumer's use of the dirty good is small relative to aggregate consumption and pollution. Under that assumption, even when individuals are not identical, each one of them may know that others respond to prices and income in the same way as he does himself, but it is still not rational for him to take this into account in his own consumption decisions. This is simply the assumption of perfectly competitive behaviour.

sum of utilities, which is simply $W = nU$. The production possibility schedule is assumed to be of the linear Ricardian form, so that it can be written as

$$-wnh + ny + pnx + qz = 0. \quad (9)$$

Here w, p and q are the technical production coefficients. The symbols have been chosen to reflect the fact that under competitive conditions the coefficients will be equal to equilibrium producer prices, again with the y-good as the *numéraire*.

Social welfare maximization is now characterized by the first order optimality conditions

$$U_l / U_y = w, \quad (10)$$

$$U_x / U_y + n\, U_e / U_y = p, \quad (11)$$

$$n\, U_z / U_y = q. \quad (12)$$

Comparing (10) and (11) with the conditions for individual utility maximization (3) and (4), we can characterize the first-best optimal tax structure. This is simply $t = 0$ and $\tau = -\, nU_e / U_y$. There should be no distortionary tax in the labour market, and the tax on the dirty good should reflect the marginal social damage, i.e. the sum of the marginal damages imposed on all individuals. Finally, the public good should be supplied according to the Samuelson (1954) optimality rule: the sum of the marginal willingness to pay across all individuals should equal the marginal cost or the marginal rate of transformation. In this case the MCF is unity, since the marginal social benefit is simply equated to the marginal social cost. If this combination of taxes and public goods supply leads to a deficit or surplus in the government's budget constraint, the gap should be filled by a lump sum transfer from or to the consumers, i.e. by an adjustment of the lump sum income term, a.

3. **Public goods supply with distortionary taxes.**

We now abandon the assumption that lump-sum taxes are feasible. In the real world of heterogeneous consumers, individualized lump-sum taxes would be the ideal way of raising revenue while simultaneously redistributing income, but for well-known reasons such taxes are not practically feasible. In a model economy of identical individuals, however, there is no real justification why it should be impossible to collect the same amount in taxes from all individuals. In this context the assumption must therefore be seen simply as an *ad hoc* device to concentrate on the efficiency properties of a second-best optimum situation. The government has to finance the cost of supplying the public good partly by means of the distortionary income tax and partly through the Pigouvian tax on the dirty good. As a natural point of reference, we begin by deriving the conditions for a second-best optimum. What is the optimal supply of the public good, and what is the best combination of the labour income tax and the Pigouvian tax?

The government's budget constraint says that taxes collected must equal expenditure, so that

$$ntwh + n\tau x = qz, \qquad (13)$$

while the social welfare function can be written on dual form as

$$W = n\, V(w(1-t), P, a, z, e), \qquad (14)$$

where a must now be understood as constrained to zero.

We are now in a position to study how the cost of public goods supply depends on the costs of tax finance. There are in principle two ways in which this can be done. We could, as Atkinson and Stern (1974) did, adopt the framework of optimal taxation and public goods, or we could, as is more or less implicit in cost-benefit analysis, consider a balanced budget change in public expenditure and taxes without assuming anything about optimality. The first approach gives the most straightforward definition of the MCF as a shadow price emerging from the optimality conditions. The second, however, is much less restrictive and more relevant for the view of the MCF as a practical tool for the evaluation of public projects. In the following we shall pursue both approaches and see how they are related.

Starting within the optimality framework, the problem is to maximize (14) with respect to the tax rates t and τ, subject to the budget constraint (13). The Lagrangian can be written as

$$\Lambda = n\, V(w(1-t), P, z, e) + \mu[ntwh + n\tau x - qz]. \qquad (15)$$

Keeping in mind that $e=nx$, and that producer prices are constant, the first-order conditions for this optimization problem[6] are

$$\partial\Lambda/\partial t = - n\lambda wh + nV_e n(\partial x/\partial t) + \mu[nwh + ntw(\partial h/\partial t) + n\tau(\partial x/\partial t)] = 0, \qquad (16)$$

$$\partial\Lambda/\partial\tau = - n\lambda x + nV_e n(\partial x/\partial P) + \mu[nx + ntw(\partial h/\partial P) + n\tau(\partial x/\partial P)] = 0, \qquad (17)$$

$$\partial\Lambda/\partial z = nV_z + nV_e n(\partial x/\partial z) + \mu[ntw(\partial h/\partial z) + n\tau(\partial x/\partial z) - q] = 0. \qquad (18)$$

Although the three conditions provide a joint characterization of the optimal tax-expenditure policy, it is natural to see (18) as the optimality condition for public goods supply. Dividing through this equation by λ and rearranging terms, we obtain

$$n(V_z/\lambda) + (nV_e/\lambda)n(\partial x/\partial z) = \gamma[q - ntw(\partial h/\partial z) - n\tau(\partial x/\partial z)], \qquad (19)$$

where $\gamma = \mu/\lambda$. The interpretation of condition (19) is straightforward. The first term on the left is the Samuelson sum of the marginal rates of substitution, i.e. the direct benefit of the increase in public goods supply. The second term is the indirect benefit that arises because the public good may cause a change in the amount of environmental damage. This benefit is positive if the dirty good and the public good are substitutes ($\partial x/\partial z<0$) and negative if they are complements ($\partial x/\partial z>0$). On the

[6] The form of the optimality conditions reflects the assumption of separability of e. In the general case the partial derivatives such as $\partial h/\partial t$ would have to be replaced by derivatives dh/dt etc., which would take account of the environmental feedback on demands and supplies. See Sandmo (2000, ch. 6 for details).

right-hand side, q is the direct resource cost of the public good, as before. The direct resource cost is modified by the remaining two terms in square brackets. These terms represent the change in tax revenue that is generated by an increased public goods supply; to the extent that the public good increases the tax bases, it counteracts the adverse distortionary effects of the taxes, so that real resource costs are lowered. Finally, the parameter γ represents the ratio of the marginal utilities of income in the private and public sector and is a measure of the inefficiency of the tax system. It is this parameter that will be identified with the marginal cost of public funds, so that MCF = γ.

However, a question may be raised as to whether γ alone is too restrictive as a measure of the MCF. In particular, one might argue that the tax revenue effects should also somehow be included, since they too characterize the second-best optimality condition in contrast to the first-best Samuelson rule. Something may be said for this, but the issue depends on how one sees the practical role of the concept of the MCF. The point of view taken here is that the potential usefulness of the MCF lies in cost-benefit analyses of public goods projects funded by general tax finance, and that it should be defined in a way that will make it the same for all projects. But the bracketed expression in (19) is project specific, since the only realistic assumption is that each public good is characterized by a different degree of substitutability or complementarity with private taxed goods. γ, on the other hand, is a characteristic of the system of tax finance and does not vary with the nature of the project. Thus, the modification of the direct resource cost via the effect of the public good on the tax base should be seen as a separate operation, to be performed before the MCF is applied to the net resource cost of the project[7].

4. An optimal tax structure.

[7] Atkinson and Stern (1974), in their comparison of the optimality rules for public goods under first best and second best conditions, do not make this conceptual distinction between the two types of effects, but it should be kept in mind that their paper was written long before the modern focus on the MCF as a tool for decentralized decision-making in the public sector

When both tax rates have been chosen in accordance with the second best optimal tax criterion[8], it follows that the MCF at the optimum must be the same, *whatever the source of tax finance.* This follows by noting that when (16) and (17) both hold, we must have that

$$[wh - n(V_e/\lambda)(\partial x/\partial t)]/[wh + tw(\partial h/\partial t) + \tau(\partial x/\partial t)] = \gamma = \qquad (20)$$

$$[x - n(V_e/\lambda)(\partial x/\partial P)]/[x + tw(\partial h/\partial P) + \tau(\partial x/\partial P)]$$

Can anything be said about the common value of the two expressions for the MCF? Simple conditions in terms of these demand and supply derivatives seem difficult to derive. Still, there are two important messages to take away from (20). The first is the equality of the two measures of the MCF, and that it is only in the case where the whole tax system has been optimized that the concept of *one* MCF is a valid one. The second message has the form of a caution. It might be tempting to conclude that the common value of the MCF must be lower in this case that it would have been, had the green tax for some reason not been available – the reason being presumably that the value of the objective function must increase with the number of policy instruments that can be used. The fallacy in this line of reasoning is that it is not the MCF but social welfare which is the policy objective, and that there is no one-to-one correspondence between social welfare and the value of the MCF. We might still think that this would be a reasonably realistic conclusion, but it does not follow directly from the simple logic of optimization theory.

5. **Beyond optimization: The reform perspective.**

In the previous section we considered the marginal cost of public funds as a shadow price related to the solution of an optimization problem. But if the MCF is to be used

[8] The reader may check that conditions (16) and (17) together imply the property of additivity, as it was called in Sandmo (1975), or the principle of targeting. Solving the two equations for t and τ, it can be shown that the characterization formula for the income tax rate is a generalized version of the Ramsey inverse elasticity and is independent of the marginal social damage, while the formula for the green tax is the weighted sum of a Ramsey term and one reflecting the marginal social damage. Of the available

in an evaluation of particular proposals for increased supply of a public good, the optimality setting is very restrictive. A more natural framework is that of the theory of tax reform, although extended to take account of a possible increase in public expenditure. The question is then whether increased expenditure increases welfare, given the nature of the taxes that are used to finance it.

We begin by studying the condition for welfare improvement following a simultaneous change in tax rates and public goods supply. If we take the differential of the social welfare function (14), the condition can be written as:

$$dW = [- n\lambda wh + nV_e n(\partial x/\partial t)]dt + [-n\lambda x+nV_e n(\partial x/\partial P)]d\tau + [nV_z+nV_e n(\partial x/\partial z)]dz > 0. \quad (21)$$

The increased expenditure must be balanced by a corresponding increase in tax revenue, so that from the government's budget constraint we must have that

$$[nwh+ntw(\partial h/\partial t)+n\tau(\partial x/\partial t)]dt +[nx+ntw(\partial h/\partial P)+n\tau(\partial x/\partial P)]d\tau + [ntw(\partial h/\partial z)+n\tau(\partial x/\partial z)-q]dz = 0. \quad (22)$$

We can now use (21) and (22) to analyze the conditions for increased public goods supply to be welfare improving under alternative assumptions about the source of tax finance.

An interesting issue is of course the extent to which the analysis of optimal taxation provides any insights that are useful for the reform perspective. It is useful to explore the connection between the two approaches via the simple case where the green tax is the only source of finance. One might perhaps think that this implies a reversion to the first best. This is not true, however, since there is no guarantee that the revenue generated by the first best level of the green tax would finance an optimal amount of the public good. The optimal resource cost of the public good might be either higher or lower than this, and budget balance must be achieved through a simultaneous adjustment of the tax and the public goods supply. The next section therefore

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taxes, it is only the tax on the dirty good which, in the optimal design of the tax system, is targeted on considers the MCF for pure green finance and contrasts the optimum tax approach with that of the reform perspective.

6. **The case of pure green finance.**

We start by considering the analysis in an optimal tax framework. With $t=0$, (19) becomes

$$n(V_z/\lambda) +(nV_e/\lambda)n(\partial x/\partial z) = \gamma[q - n\tau(\partial x/\partial z)]. \qquad (23)$$

The MCF, which will now be written as γ_τ to indicate the source of finance, can now be obtained from the lower line of (20), after setting $t=0$, as

$$\gamma_\tau = [x - n(V_e/\lambda)(\partial x/\partial P)]/[x + \tau(\partial x/\partial P)]. \qquad (24)$$

As pointed out above, one's intuition might suggest that with purely green taxation, the MCF could well be below one. However, the form of (24) does not immediately indicate that this is the case. A more careful analysis of this equation is accordingly called for.

Note first that the expression in the denominator represents the derivative of tax revenue with respect to the green tax. In standard optimal tax theory the tax revenue effect is positive at the optimum; an increase in the tax rate inflicts a loss on consumers, and to offset this loss, the tax revenue effect must be positive. In other words, each tax rate must be on the rising part of its 'Laffer curve'. In the case of a green tax, however, this is not necessarily the case. An increase in the price $P=p+\tau$ involves a loss to the consumer through the negative effect on purchasing power, but at the same time it improves the environment, which is a gain. A higher tax at the margin might therefore represent a net gain for the consumer, and in this case it could happen that the marginal tax revenue effect could be negative at the optimum[9]. But

improving the environment.

[9] It is easy to understand why an optimal green tax might be on the downward-sloping part of its "Laffer curve". If the marginal social damage is high enough, as in the case of toxic waste, it might

the conventional assumption of a positive revenue effect seems to be the more interesting and relevant one, and I shall concentrate on this. Given that assumption (in addition to the assumption that the dirty good is normal), it is easy to see that (24) implies the following:

$$\gamma_\tau > 1 \text{ if and only if } \tau > -n(V_e/\lambda). \qquad (25)$$

In words, the marginal cost of public funds exceeds one in the case where the optimum green tax rate exceeds its Pigouvian level; conversely, it is less than one if the tax is below this level. The intuition behind the result is easy to understand. When the tax exceeds its Pigouvian level, its role *on the margin* becomes that of an ordinary distortionary tax; it is higher than required to equalize marginal social benefits and costs. In that case the MCF must necessarily be greater than one. When, on the other hand, it is below that level, an additional increase goes further in the direction of internalizing the externality, so that there is a social benefit involved in a higher tax rate. The higher tax leads to a lower degree of distortion, so that the MCF becomes less than one.

It is worth noting that the borderline case $\tau = -n(V_e/\lambda)$, where the second-best tax rate coincides with the first best, also has the implication that the condition for optimal public goods supply (23) becomes simply $n(V_z/\lambda) = q$. When the green tax – by coincidence - internalizes the externality perfectly, there is no need to take account of the effect of public goods supply on the environmental externality, and the Samuelson optimality condition holds without modification.

Having studied the case of pure green finance from an optimum taxation viewpoint, we now revert to the reform perspective. Here no assumption is being made about the optimality of taxes and expenditure. With pure green finance we have that $dt=t=0$ in (21) and (22). Eliminating $d\tau$ from the last expression, we can rewrite (21) as

indeed be optimal to set the tax at a level where a reduction of the tax would increase revenues. One of the reasons why, in this particular context, this case is of less interest, is that when the optimal tax is close to being prohibitive, regulations, e.g. in the form of outright prohibition, would do just as well as taxes.

$$dW/dz > 0 \leftrightarrow n(V_z/\lambda) + (nV_e/\lambda)n(\partial x/\partial z) > \gamma_\tau[q - n\tau(\partial x/\partial z)], \qquad (26)$$

where, as before,

$$\gamma_\tau = [x - n(V_e/\lambda)(\partial x/\partial P)]/[x + \tau(\partial x/\partial P)]. \qquad (27)$$

The expression for the MCF is the same as (24), while the condition for welfare improvement has the same form as (23); the difference is simply that the equality sign in (23) has been replaced by an inequality. Whether the MCF is greater than or equal to one depends on whether the green tax is above or below its first best level. Thus, the basic logic of the analysis and the usefulness of the MCF concept is valid outside of the optimal tax-expenditure framework.

In comparing the identical expressions (24) and (27), it should of course be kept in mind that although the expressions have the same form, the actual *value* of the MCF is unlikely to be the same. In the case represented by (24) the value has been derived as a shadow price in a second-best optimization problem, while in (27) there are no such restrictions on taxes and quantities. The important message – which is easily seen to be valid beyond this particular example - is that the correct way to think about the components of the MCF is independent of any optimality assumptions. This is consistent with the more general analysis of the principles of cost-benefit analysis by Drèze and Stern (1987), who also point out that the definition of shadow prices does not depend on the assumption that the government has carried out an optimal plan.

7. **A fixed distortion in the labour market.**

A natural extension of the previous analysis is to the case where the green tax is still the marginal source of finance, but where there is a fixed tax distortion in the labour market. This case can be seen as representing the more general case where the income tax system has been designed to a large extent with distributional objectives in mind and where the marginal tax rate accordingly is not adjusted to finance the marginal expenditure on public goods.

With the insights established in the previous section, it is now natural to focus on the reform framework. Thus, in (21) and (22) we have $t>0$, but $dt=0$. Proceeding as above we derive the expression for the MCF as

$$\gamma_\tau = [x - n(V_e/\lambda)(\partial x/\partial P)]/[x + tw(\partial h/\partial P) + \tau(\partial x/\partial P)]. \qquad (28)$$

To study the condition for $\gamma_\tau>1$, we continue to assume that the effect on tax revenue of raising τ is positive. The condition then becomes

$$[\tau + n(V_e/\lambda)](\partial x/\partial P) < -tw(\partial h/\partial P).$$

Dividing through by $\partial x/\partial P$, which is negative, we may conclude that

$$\gamma_\tau>1 \text{ if and only if } [\tau + n(V_e/\lambda)] > [-tw(\partial h/\partial P)/(\partial x/\partial P)]. \qquad (29)$$

The left-hand side of the inequality is the deviation of the green tax from its first-best level.[10] The right-hand side has the sign of $\partial h/\partial P$. In the absence of quantitative information about the relationships involved, one firm conclusion that can be drawn is the following:

$$\gamma_\tau>1 \text{ if } \tau > -n(V_e/\lambda) \text{ and } \partial h/\partial P<0. \qquad (30)$$

It also follows that

$$\gamma_\tau<1 \text{ if } \tau < -n(V_e/\lambda) \text{ and } \partial h/\partial P>0. \qquad (31)$$

Both (30) and (31) state *sufficient* conditions for the MCF to be greater than or less than one, respectively, but each of them also alerts us to the difficulties involved in providing necessary conditions in this type of setting. From our previous discussion of the benchmark case of pure green finance, we would indeed expect the MCF to exceed one in the case where the green tax is above its Pigouvian level. If $\partial h/\partial P=0$, so that labour supply had been independent of the level of green taxation, that result would have carried over to the present case. But when the cross price effect differs from zero, the increase in the price of the dirty good affects the magnitude of the labour market distortion. Suppose that (30) holds, so that labour and the dirty good are complements. Then, a further increase in τ would exacerbate the distortion in the market for the dirty good, while simultaneously making the distortion in the labour market more severe by lowering the supply of labour. This makes the MCF unequivocally greater than one. If, on the other hand, labour and the dirty good had been substitutes, an increase in τ would involve an increase in one distortion and a decrease in the other. Depending on the relative strengths of the two effects, the MCF could be either less than or equal to one.

Condition (31) has a similar interpretation. A value of τ below its Pigouvian level would seem to indicate an MCF less than one. But because of the effect on labour supply of an increase in the price of the dirty good, it is only in the case of substitutability $(\partial h/\partial P>0)$ that this conclusion can be firmly extended to the case of a distorted labour market.

In connection with condition (31) there is a special case which deserves particular attention, viz. that where the initial value of τ is zero. In discussions of the double dividend from a green tax reform, the thought experiment that some people seem to have in mind is where green taxes are introduced into an overall tax system where they were previously not present. In general, (28) indicates that such a reform will imply an MCF below unity provided that the green tax does not sufficiently strongly magnify the effects of previous tax distortions in the economy.

8. **The income tax as the marginal source of funds.**

[10] Or, more correctly, the deviation of the tax from its first-best *characterization*. In a distorted equilibrium the value of an environmental improvement will in general differ from what it would have been under first-best conditions, although its analytical representation has the same form.

As a further thought experiment, we may briefly consider the case where the increase in public expenditure is financed by means of increased income taxation and where the level of green taxes is held constant. Going back to the inequalities (21) and (22), this involves setting $d\tau=0$, and the marginal cost of funds can then be derived as

$$\gamma_t = [wh - n(V_e/\lambda)(\partial x/\partial t)]/[wh+tw(\partial h/\partial t)+\tau(\partial x/\partial t)]. \qquad (32)$$

Again assuming the denominator of the right-hand side to be positive, it follows that

$$\gamma_t>1 \text{ if and only if } [\tau+n(V_e/\lambda)](\partial x/\partial t)<-tw(\partial h/\partial t). \qquad (33)$$

This condition does not give us a clear answer as to the numerical magnitude of γ_t. It does, however, give rise to the same type of classification as (29), which, it will be recalled, concerns the "reverse" case, where *t* is fixed and the green tax is the marginal source of funds. Let us assume that labour supply is a decreasing function of the marginal tax rate. Sufficient conditions for (33) to hold are then either

- that the green tax is below its Pigouvian level and that the demand for the dirty good is an increasing function of the income tax rate, or

- that the green tax is above its Pigouvian level and that the demand for the dirty good is a decreasing function of the income tax rate.

In both cases the economic intuition behind the conclusion that $\gamma_t>1$ is that the increase in the rate of income tax, in addition to worsening labour market efficiency, also magnifies the existing distortion in the market for the dirty good. It is also worth pointing out than while in the standard analysis of the income tax the MCF equals one if the labour supply elasticity is zero, this is not the case here. This is easily seen from (33). The two cases of sufficient conditions mentioned above would in that case continue to yield an MCF in excess of one, since the income tax affects the demand for the dirty good.

These are not the only sets of sufficient conditions that lead to firm qualitative conclusions about the magnitude of the marginal cost of funds for income tax finance. A number of other combinations of assumptions could be listed (one could e.g. repeat the above exercise for the case of $\partial h/\partial t>0$), but they do not yield much additional insight into the nature of the problem. The general message is as before that under second best conditions it is essential to consider the interaction between distortions in different markets.

9. A simplified rule for green taxes.

A weak point of optimal tax theory is its neglect of the administrative costs of the tax system. Including the administrative costs of taxes explicitly into the optimization framework raises a number of difficulties, particularly with regard to the non-convexities involved, and to tackle these is far beyond the scope of the present paper. However, one topic that deserves discussion in the present context is the question of decentralization of tax decisions. If green taxes and environmental charges come to be more widely used in the coming decades, there will be a heavy burden on the ministry of finance, in terms of information collection and decision-making capacity, if all decisions about taxes are to be its responsibility. A more realistic scenario is one where decisions about a large number of environmental taxes and charges become decentralized to the ministry of the environment or perhaps regional authorities with responsibility for local pollution control. In that case, it would be unreasonable and impractical to ask all these units to take account of all possible secondary effects of the tax system, e.g. the green tax effects on labour market performance. Instead, the central government should provide more simple guidelines for lower level units, and one such guideline might be to set environmental taxes according to the first-best Pigouvian formula $\tau = - n(V_e/\lambda)$. Calculations of the MCF for the central government would then be based on the assumption that revenue is to be generated through variations in the income tax rate t, assuming that those responsible for environmental taxes keep these linked to the expression for marginal social damage.

The MCF can now be derived as a special case of (32), namely where $\tau = - n(V_e/\lambda)$. We then get

$$\gamma_t = [wh + \tau(\partial x/\partial t)]/[wh+tw(\partial h/\partial t)+\tau(\partial x/\partial t)] \quad . \qquad (34)$$

It follows immediately, assuming again that the tax revenue effect is positive, that

$$\gamma_t > 1 \text{ if and only if } tw(\partial h/\partial t) < 0. \qquad (35)$$

With a positive tax rate, the MCF exceeds one if the labour supply elasticity with respect to the tax rate is negative, and is below one if is positive. This is a very simple condition, providing a clear focus on what determines the magnitude of the efficiency costs of financing public goods through central government finance. The decentralization scheme on which this condition is based is suboptimal in the sense that one can always do better by coordinating decisions – in principle. But the decentralization rule is likely to be better in terms of administrative resource use, representing a practically feasible division of responsibilities within the public sector.

10. Concluding remarks.

Simple economic intuition suggests that when the supply of public goods can be financed by means of environmental taxes, the method of finance yields an efficiency gain to the economy; hence, the marginal cost of public funds should be less than one. The present paper has shown that this intuition should be handled with care. Even in the case with no traditional income or commodity taxes, the intuition fails to be valid if the initial level of the Pigouvian tax is above its first best level. In the more general case where there exist both traditional and environmental taxes, the implications for the MCF depend crucially on the nature of interaction between markets. The existence of environmental taxes also has important implications for the magnitude of the MCF from traditional taxes such as the income tax. However, in all the thought experiments that we have considered, there emerges a formula for the MCF which has a strong appeal to the not-so-simple intuition that one develops from the study of optimal second best tax systems. Moreover, these formulae can be shown to be valid not only when the tax system is assumed to satisfy the conditions for second-best optimality, but also in the much less restrictive framework of a balanced-budget expansion of public goods supply.

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