ESSAY

Double Dividend Reconsidered

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Introduction

Over the past eight years, a sizable body of literature on "green tax reform" and the "double dividend hypothesis" has appeared, accompanied by a considerable degree of confusion surrounding these results and their interpretation. Much of the confusion stems from the apparent incongruities between the findings in this literature and the intuitive propositions that preceded them. Despite efforts by the authors of this literature to clarify the reasoning behind their findings and interpretations (for example, Goulder and Parry 2000), doubts and confusion persist in many quarters.

To be sure, the theoretical questions being raised are inherently complicated, and it is remarkable just how complex this particular issue has become due to the myriad of assumptions, definitions, and distinctions on which a particular interpretation may depend. Adding to the confusion are disagreements about what question is being asked, and which results are pertinent to what question. Such ambiguities can create a moving target, leading us in circles, and making it difficult to reduce the confusion or resolve the debate.

At a general level, the debate is about tax policy in a world with two tax problems: where revenue-motivated (distortionary) taxes are needed to raise revenues, and where externalities create an opportunity for environmental (corrective) taxation. In general, the questions being asked pertain to whether these two tax problems are complementary, or whether they are competing government objectives. This general question can be broken down into: 1) questions about price (Will the optimal environmental tax generally be higher or lower than the marginal social damage from pollution in the presence of revenue-motivated taxes?); 2) questions about quantity (Can environmental policy do more, or less, to improve the environment in the presence of revenue-motivated taxes?); and 3) questions about welfare effects (Does the presence of revenue motivated taxes raise or lower the welfare gains from "green tax reform" (the revenue-neutral introduction of environmental taxes)?).

Obviously, these questions are interconnected, and answers to one may lead intuitively to inferences about the others. Indeed, while much of the recent literature has been based on the price question, their conclusions have emphasized the inferences to be drawn about the welfare effects of "green tax reform". Some analysts have evaluated whether setting the environmental tax equal to the marginal social damage from pollution is welfare maximizing (e.g., Bovenberg and de Mooij 1994, Parry 1995), others have judged whether the optimal environmental tax should be higher or lower than marginal social damages (e.g., Bovenberg and van der Ploeg 1994, Bovenberg and Goulder 1996, Fullerton 1997).

The connection between the optimal environmental tax and the welfare gains from green tax reform are closely tied with the "double dividend hypothesis," which suggests that using the revenues from environmental taxes to lower preexisting revenue-motivated taxes will produce an added welfare gain. Since the Pigouvian principle calls for equating the environmental tax to the marginal social damage, the introduction of an additional welfare gain should lower the net cost of environmental taxation, and, intuitively, this should make it possible to raise the environmental tax above marginal social damage. The term "double dividend" became widely used following Pearce (1991), who suggested that this could make the effective environmental tax (in terms of its distortionary cost) 20 to 50 percent lower than its nominal value.[1]

Nevertheless, while the authors of the recent literature agree that using pollution tax revenues to finance reductions in preexisting taxes is welfare improving, they have found—surprisingly—that the optimal environmental tax generally lies below the marginal social

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[1] Other literature frequently cited as supportive of the double dividend hypothesis includes Tullock (1967), Terkla (1984), Lee and Misiokek (1986), and Oates (1995).

damage from pollution. Herein lies the apparent incongruity and source of confusion of their findings.

The current essay attempts to clarify these issues by drawing attention to two key distinctions that, in my view, are central to the analysis but have been overlooked in the recent literature. One of these involves distinguishing between social and private valuation. The other involves distinguishing between the two main types of environmental externalities, those that affect productivity and those that affect utility directly.

On the distinction between social and private values, first-principles in welfare economics and social benefit-cost analysis tell us that in a distorted economy, social valuations will differ from private valuations and that to interpret optimality conditions it is the social, or shadow, value of resources that should get our attention. This is true in an economy distorted by taxes or externalities. Thus, I take the position that the present analysis should focus on the social rather than the private value of resources and income. In particular, this means identifying the social marginal utility of income, rather than the private marginal utility of income, as the relevant and appropriate numeraire unit of value for social welfare considerations (more on this below).

On the second point, there exist two distinct types of environmental externalities: production externalities that affect factor productivity, including labor, land, and capital of various types; and amenity externalities that affect utility directly, such as visual and aural amenities and existence values. Since many examples of both types of externalities can be cited (indeed many environmental problems involve both kinds of externalities), I take the position that both types should be given equal consideration in the present analysis—since the results and interpretations may differ by externality type.

Before addressing the specific questions noted above, several caveats are in order. Unless indicated otherwise, all the analyses discussed below pertain to the kinds of models which have been used in the recent literature, ones where certain restrictive assumptions have been introduced to make the analysis tractable. The discussion will therefore pertain to models with homogeneous consumers where all goods are assumed to have identical demands (being equal substitutes for leisure), where labor is the only productive factor and source of income, and where, in the case of an amenity externality, environmental quality is weakly separable in utility. These restrictions ensure that the optimal revenue-motivated tax (in the absence of externalities) will be equal for all goods.

Additionally, government is assumed to rely on distortionary taxes to raise a fixed amount of revenue. The revenue can be assumed to be returned lump sum to consumers or used to provide a public good that is separable in utility. Thus, the starting point for discussions of green tax reform is a situation with preexisting revenue motivated taxes. These may take the form of either a tax on labor income (denoted as an “income tax normalization”) or—equivalently—uniform taxes on all commodities (denoted as an “expenditure tax normalization”). The choice of normalization for the preexisting tax program does not affect the analysis in any real way, as pointed out by Fullerton (1997) and Schöb (1997). It is, however, important to recognize that for the income tax normalization approach, household income has been converted as a consequence to “net income units.” For the expenditure tax normalization, it is the differential between the optimal taxes on polluting and non-polluting goods that defines the “environmental tax.”

The Optimal Environmental Tax

The question of whether the second-best optimal environmental tax will be higher or lower than the marginal social damage from pollution has been the cornerstone of the recent literature. There is little ambiguity about what the optimal environmental tax should be. For a given theoretical or numerical model, the optimal environmental tax can be identified precisely.[2] But without a point of reference for comparison, there is no way to interpret this result, or to answer the questions being asked in the current literature. Interpretation involves comparing the optimal environmental tax to marginal social damage, and this requires defining marginal social damage explicitly.

From society’s perspective, marginal social damage (MSD) is based on the marginal rate of substitution between income and environmental quality. In other words, it is the social marginal disutility of environmental damage divided by the social marginal utility of income (in absolute value). Differences between private and social values occur in the current context for two reasons. First, the non-rival character of the environment means that the social marginal utility of environmental quality (or other public goods) exceeds its private marginal utility. Second, with preexisting revenue-raising taxes, the social marginal utility of income will exceed the private marginal utility of income because it includes the value of the incremental tax receipts. The

[2] This assumes we are able to distinguish between the revenue component and the environmental component of the optimal tax. This has been accomplished by using an income tax as the revenue-motivated tax (e.g., Bovenberg and de Mooij 1994), or by defining the environmental tax as the difference between the optimal taxes on polluting and non-polluting goods (Fullerton 1997; Jaeger 2001a).

definition of the social marginal utility of income was identified and formalized by Diamond (1985), and defined as "the sum of gains from individual consumption and from the marginal propensity to pay taxes out of income."

As in social benefit-cost analysis, the distinction between private and social value is crucial, so we need to be absolutely clear on this point. To illustrate, consider a first-best world where a one-unit increase in an individual's income will be spent on consumer goods from which they derive 10 "utils" of utility. In this case the private marginal utility of income is 10 utils, and the social marginal utility of income is 10 utils as well. There is no difference between the two values in the first-best case.

Now assume that revenue-motivated taxes are introduced on all consumer goods in order to finance the provision of a public good. In the presence of these taxes, a one-unit increase in an individual's income will be spent on goods whose prices now include these taxes. This will generate some tax revenue, but it will also lower the purchasing power of the incremental unit of income compared to the first-best case. Given the loss of purchasing power, let's assume that the private marginal utility of income is now only 6 utils. Assume also that the incremental tax receipts are used to provide an additional increment of the public good, which has a social value of 4 utils. Thus, the social marginal utility of income could still equal 10 utils in this example due to the contribution of additional revenues, but the private marginal utility of income will be less than that, in this case only 6 utils.

In an economy with preexisting taxes, if environmental damage reduces labor productivity and thus lowers income, which of these definitions of the value of a unit of income should be used, 10 utils or 6 utils? Since a one-unit loss of income will reduce social welfare by 10 utils, society should recognize 10 utils as the social marginal utility of income. If we were to look only at the private marginal utility of income, we would understate the social cost of environmental damage in this hypothetical example.

This definition of value differs from the one used in the recent literature, where changes in income are valued from the private, or household, perspective rather than from society's perspective.[3] This means that, according to the recent literature, only that portion of an incremental unit of income spent directly on consumption is reflected in the numeraire unit of value. If a production externality lowers income, the definition involving private valuation only includes the reduction in private consumption, not the reduction in public revenues. Valuing an incremental change in income in this way does not reflect a Pareto efficient allocation: it does not correspond to the difference between *ex ante* and *ex post* Pareto states for a unit change in income.

If we define marginal environmental damages based on this private measure of value—call it "marginal private damages" or MPD—complications arise. For example, MPD will be less than MSD in the case of a production externality, but it will be higher than MSD in the case of an amenity externality. To be clear on this point, let's look at each type separately.

For a production externality where labor productivity is an increasing function of environmental quality, a decline in environmental quality will impose a cost on individuals and society. The cost to society will exceed the cost to an individual for two reasons. First, given the non-rival character of the environment, all individuals will see their labor productivity decline and the social cost will reflect the aggregate loss of income across all individuals. Second, in the presence of revenue raising taxes, the loss to society will include the social value of lost tax receipts due to the decline in income. If workers are sickened and cannot work, or if crop yields decline due to pollution, the social cost includes not only the lower consumption experienced by individuals, but also the reductions in public goods or transfers resulting from the lost tax receipts. Thus, MPD will be lower than MSD.

In the case of an amenity externality, the reverse occurs. Environmental damage is first measured in utility units, aggregated across households, and then converted to dollars dividing by the value of a numeraire unit of income. MPD in this case is defined as the marginal (dis)utility of environmental damage divided by the private marginal utility of income. Using the private marginal utility of income as the numeraire rather than the social marginal utility of income, however, places a relatively smaller measure of value in the denominator of MPD, which means the dollar value of MPD will exceed that of MSD.[4]

[3] Throughout the recent literature the Lagrange multiplier on the household budget constraint, λ, is used to define marginal social damage (see for example, Bovenberg and de Mooij 1994; Bovenberg and Goulder 1997).

[4] In the amenity case, changes in environmental quality may also affect revenues if environmental quality is a substitute (complement) for leisure, which would raise (lower) marginal social damage. This possibility has generally been abstracted from in the recent literature by assuming that environmental quality is weakly separable in utility, so that these effects will not arise.

In a first-best setting with no revenue-motivated taxes, MSD and MPD are equivalent because the social marginal utility of income equals the private marginal utility of income. When revenue-motivated taxes are present however, the social marginal utility of income will exceed the private marginal utility of income, and the divergence between the two will grow with increasing revenue requirements. Thus, an increase in revenue requirements has the effect of exacerbating the divergence between MSD and MPD, but in opposite directions for the two types of externalities.

Indeed, as Figure 1 illustrates, the relationship between the optimal environmental tax and MSD is a function only of the parameters in the model (those that determine the marginal excess burden of taxation), and not dependent on which type of externality is under consideration. We can also see in Figure 1 that for revenue levels that cannot be satisfied by a Pigouvian tax alone (greater than R^0), the optimal environmental tax exceeds MSD and rises relative to MSD with rising revenue requirements (see also Jaeger 2001b).

By contrast, the relationship between the optimal environmental tax and MPD will depend on which type of externality is being considered. In the case of a production externality, the optimal environmental tax will exceed MPD^P and the ratio between the two will be greater than the ratio between the optimal environmental tax and MSD, as illustrated in Figure 1. In the case of an amenity externality, however, increases in revenue requirements above R^0 result in MPD^A rising faster than the optimal environmental tax. This is also illustrated in Figure 1, indicating how the ratio of the optimal environmental tax to MPD^A would actually decline even though the optimal environmental tax is rising. The rise in MPD^A results from the decline in the private marginal utility of income as a greater proportion of incremental income is being taxed and allocated to public consumption.

These same observations can be made with explicit theoretical expressions derived using an approach similar to Sandmo (1975). For the classes of models used in the recent literature, the optimal environmental tax, t*, can be expressed as a function of MSD and the revenue-motivated tax rate (Jaeger 2001b). The expression can be written as

$$(1) \qquad t^* = \left(\frac{\alpha'}{\mu'(1-t_L)}\right) MSD' = \left(\frac{\alpha(1+t_C)}{\mu}\right) MSD$$

where α denotes the social marginal utility of income, μ denotes the social marginal utility of public revenues, and t_L is the income tax rate. The first and second expressions in (1) pertain to the income tax normalization (involving t_L) and the expenditure tax normalization (involving t_c), respectively.[5]

The term in brackets may be greater or less than one since we understand that $\alpha<\mu$ and that $(1-t_L)<1$. However, for parameter values consistent with the models and assumptions in the recent literature, the expression in brackets will be in the range of 1.4 to 1.6, indicating that the optimal environmental tax should be 40 to 60 percent above MSD (Jaeger 2001a, b).

If we want to use MPD as our benchmark, no analytical expression exists for the production externality case. For an amenity case in which environmental quality is assumed to be weakly separable in utility, the relationship can be expressed in terms of MPD and the private marginal utility of income, λ, as

$$(2) \qquad t^* = \left(\frac{\lambda'}{\mu'(1-t_L)}\right) MPD' = \left(\frac{\lambda(1+t_C)}{\mu}\right) MPD$$

This relation is equivalent to the one derived by Bovenberg and Goulder (1996), although the identity $\lambda' = \lambda/(1-t_L)$ has been substituted into their expression so that λ and μ are expressed in the same "net income" units. This substitution has no effect on the value of the expression. Based on parameter values for the kinds of models and assumptions found in the recent literature, the expression in (2) suggests that t* may be 5 to 20 percent below MPD for the amenity case.

For the case of a production externality, the optimal environmental tax has been estimated to exceed MPD by more than 70 percent, based on a numerical model of the U.S. economy (Jaeger 2001a).

With MPD as the chosen benchmark, and with a focus on amenity externalities, the recent literature observed that t* would generally lie below MPD whenever revenue requirements exceeded R^0. As revenue requirements increase, t* will lie even farther below MPD—but this is because MPD is increasing faster than t* due to the decline in the private marginal utility of income in the denominator. The authors of the recent literature, however, appear to have assumed that MPD is unaffected by increases in revenue requirements, and they conclude that the optimal environmental tax declines with rising revenue requirements.

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[5] Parameters in each expression are normalized in consistent and appropriate units (a prime (') indicates parameters are expressed in net income units consistent with the income tax normalization. The difference, μ-α, defines the marginal excess burden of taxation. The two normalizations are equivalent given that $1+t_C = 1/(1-t_L)$ and $x' = x/(1-t_L)$ for all x.

This interpretation has led to the rejection of the double dividend hypothesis. For example, Fullerton (1997) characterizes the "strong view" of the double dividend hypothesis as suggesting that any additional revenue requirements should be met by raising the tax on the dirty good by more than the taxes on the clean goods. He concludes that "the important and correct result of Bovenberg and de Mooij is that this strong view is flawed."(p. 225). As illustrated in Figure 1, however, the rising optimal environmental tax implies that, for the expenditure tax normalization Fullerton has in mind, the tax on the dirty good should, indeed, be raised by more than the tax on the clean good. Fullerton's interpretation overlooks the fact that both the environmental tax and MPD are rising, and that MPD is rising faster than the optimal environmental tax.

Had the recent literature modeled a production externality rather than an amenity, the use of MPD as their benchmark would have led them to the opposite conclusion. They would have observed that the optimal environmental tax rises steeply relative to MPD—even more quickly than it does relative to MSD.[6] Had this situation occurred, presumably the authors of the recent literature would have concluded that the double dividend hypothesis was valid. Indeed, two papers involving production externalities have recently obtained precisely this kind of result, one that runs counter to the early amenity models (Williams 2000; Parry and Bento 1999). In these cases, however, the authors introduce a new "benefit-side tax interaction" effect to explain their findings.

In sum, given the well-established rationale for using shadow values in benefit-cost analysis, it should not be surprising that comparisons between private valuations and the marginal relationships expected from a social optimization problem will give rise to results that are inconsistent with our intuition.[7]

Environmental Quality

Armed with the general-equilibrium result summarized above that the optimal environmental tax will generally lie above MSD, we can infer that the quantity of the environmental good ("environmental quality") will also be higher in the second-best setting than in the first-best. This result has been shown analytically by Gaube (1998), independent of any comparison between the optimal environmental tax and marginal damages. Like Fullerton (1997) and Schöb (1997), Gaube (1998) points out that, intuitively, a revenue-raising income tax is equivalent to a uniform tax on all expenditures, including both polluting and non-polluting goods. For the type of models being considered, the higher the revenue-requirement the higher will be the direct or indirect tax on polluting and non-polluting goods. It follows that this will mean lower consumption and, consequently, less pollution. Thus, revenue-motivated taxes by themselves will discourage pollution in this context.

Framed differently, however, we may want to ask whether the ability of government to improve the environment—from a given second-best starting point—is strengthened or weakened in the presence of distortionary taxes. One way to respond is to appeal to the optimal environmental tax results above: As the revenue-requirements of government rise, the optimal environmental tax rate that can be justified rises as well. Thus, the ability of government to discourage pollution, as represented by the tax that can be imposed, increases with revenue motivated taxes.[8]

[6] MPD declines relative to MSD because the revenue losses associated with environmental damage are larger than those associated with a simple unit reduction in income in this model. When environmental damage reduces labor productivity, there are both income and substitution effects which reduce tax receipts.

[7] As a practical matter, in some cases it may be easier to measure private values empirically. This may be the case for contingent valuation techniques or hedonic studies, although even these methods may reflect values based on tax-deductible expenditures, pre-tax income or gross rather than net wage differentials. In such cases the conversion to equivalent shadow values will be important simply to maintain comparability among these different methods. Indeed, for cases where environmental damage reduces the productivity of labor or other assets, these measures are frequently estimated as gross income costs including the foregone tax payments that would otherwise not be reflected in marginal private damages.

[8] An alternative approach to this question has been an attempt to compare environmental control costs in a second-best setting directly with environmental control costs in a first-best setting. Parry, Williams and Goulder (1999) present numerical simulation results showing that the marginal abatement cost curve is higher in second-best than in first-best for a U.S. carbon tax model. Interpretation of their result is problematic, however, since they compare marginal costs across a given *percentage reduction* in emissions rather than at a given *level* of emissions. Because the initial emissions level is higher in the first-best case than the second-best case, a one-percentage change in their first-best model corresponds to a larger quantity of emissions than in the second-best model. Converting their results so that the comparisons are made at equal emissions levels, reveals

This result runs counter to inferences in the recent literature which invoke Pigou's reasoning and the Samuelson Condition which both point out how the optimal provision of public goods will fall as distortionary taxes rise. This reasoning is certainly correct for public goods that must be paid for out of public expenditures. Environmental quality, however, is an endowed public good, the consumption of which is not directly taxable (by assumption of non-exclusivity). By contrast, pollution, or "environmental waste disposal", is a competing environmental service which can be taxed to raise revenue (and to achieve allocative efficiency). A side effect of this is the improvement of environmental quality.

Welfare Effects of Green Tax Reform

Competing assessments of the welfare changes accompanying green tax reform have been difficult to reconcile. Moreover, clarifying this issue has been complicated by an evolving definition of the "double dividend hypothesis" and by the introduction of new concepts and phenomena (i.e., "tax interaction effect", "benefit side tax interaction effect", "gross cost"). To help clarify these issues, green tax reform can be decomposed into three components or stages and examined in terms of distinct welfare and environmental changes for each stage, as illustrated in Figure 2.

Stage 1: Correcting the market failure. In this stage, assume that allocative efficiency is simply restored. One might imagine that this is achieved by correcting a property rights failure or with Coasian bargaining, or by the introduction of an auctioned tradable permit scheme in which the revenues are returned lump sum to the economy. Polluting is costly, and after stage 1 polluters will pay the full social cost of polluting. Prior to stage 1 polluters were, in effect, being subsidized.

Thus, the changes in stage 1 can be thought of as "subsidy removal effects," and will include a reduction in pollution, an increase in the cost of consumption, and changes in labor supply that affect the tax base. For a production externality, the reduction in pollution will increase labor productivity and labor supply, which will enlarge the tax base and lower the excess burden. In the case of an amenity externality, the "subsidy removal effect" will lower the real wage and discourage labor supply, raising the excess burden.

Figure 2 indicates environmental improvement and a welfare gain in stage 1 (moving from A to B). There is, however, the possibility with an amenity externality that the net welfare change may be negative in stage 1 if the environmental gain is less than the increase in excess burden. This may arise if environmental quality is separable in utility or where environmental damages are linear (see Bovenberg and Goulder 1996 for an example). This possibility reaffirms the theory of the second-best.

Stage 2: Appropriating environmental resource rents. In this stage we assume that government appropriates the environmental resource rents, or those payments being made by polluters after stage 1. Compared to stage 1, payments by polluters are now being retained by government to finance reductions in preexisting revenue-motivated taxes. These reductions in revenue motivated taxes will lower the excess burden of taxation, increase the real wage and encourage labor supply. As indicated in Figure 2 (moving from B to C), welfare increases due to the improved efficiency of the tax program, a change representing the "double dividend." Environmental quality declines somewhat, however, because the more efficient tax program and higher real wage encourages consumption of both polluting and non-polluting goods.

Stage 3: Achieving optimal taxation. In this stage, government takes advantage of the remaining opportunity to increase welfare by adjusting tax rates to achieve optimality. With an expenditure tax normalization in mind, we recognize that after stage 2 consumers face prices that exceed social cost for all goods—except in the case of the environmental good. For a tax program to be truly optimal, each price must include a Ramsey tax premium. At point C in Figure 2, however, consumers are paying *only* the social cost of pollution: there is no Ramsey premium on this environmental service. In order to minimize the excess burden, Ramsey taxes must be introduced for all goods—including environmental "waste disposal services."

Thus, stage 3 involves introducing the optimal revenue-raising tax on pollution. This will increase welfare, improve environmental quality, and push the environmental tax above marginal social damages. After this stage, we arrive at an optimal tax program consistent with the result that the optimal environmental tax lies above MSD. This result is intuitive, analytically validated, and wholly consistent with Pearce's initial argument and inference about the double dividend. Indeed, Pearce's quantitative assessment that the effective carbon tax would be 20 to 50 percent below the nominal tax is remarkably close to the present estimations showing that MSD will lie 30 to 40 percent below the optimal environmental tax (Jaeger 2001a,b).[9]

that the second-best marginal abatement cost curve is everywhere lower than in first-best.

[9] Note that an increase in revenue requirements shifts points A through D in Figure 2 to the right, raising environmental quality relative to the first-best level. This result further contradicts the suggestion that increased revenue requirements and a "high cost of public funds

Bringing clarity to the debate surrounding the welfare changes from green tax reform has become complicated by an evolving definition of the double dividend hypothesis. Based on Pearce (1991), Goulder initially summarized the double dividend argument as implying that swaps of environmental taxes for distortionary tax may produce a double dividend by not only (1) discouraging environmentally damaging activities but also (2) reducing the distortionary cost of the tax program (1995, p. 158). Subsequently, however, Goulder revised this second component of the definition to read "(2) reduce the *overall* cost of the tax system, apart from consideration of the benefits from environmental improvement" (Goulder and Parry 2000)(emphasis added). According to this revised definition, a negative "gross cost" is a requirement for the second dividend. This new version is not only more stringent, but it also fails to reflect Pearce's recognition that carbon taxes "themselves will impose a deadweight loss which has to be set against the gain from the reduced externality from global warming"(pp. 943).

There is no apparent theoretical basis for using "gross cost" as the criterion for the double dividend, and this appears to have created yet another source of confusion. I understand the logic of separating the welfare gains due to increased allocative efficiency from those associated with increased tax efficiency—which appears to be the intended rationale for using "gross cost." However, it is not correct to assume that all welfare gains from environmental improvement are attributable to improved allocative efficiency, and that all other gains are attributable to changes in tax efficiency. For example, in stage 3 above, there is a welfare gain from optimizing the tax program by raising the environmental tax above MSD. A portion of the welfare gain from doing this comes from improving environmental quality above the level that could be justified on allocative efficiency grounds alone, making it a part of improved tax efficiency. Yet, according to Goulder's test involving "gross cost," this gain would be labeled an "environmental improvement" rather than a gain associated with optimizing the tax program. Moreover, in many other examples such as production externalities or when environmental quality is non-separable in utility, it is not obvious how one would go about separating or evaluating "gross cost." In short, it is not clear that Goulder's notion of "gross cost" is helpful in testing the validity of the double dividend hypothesis, or that Pearce's definition is inconsistent with the evidence summarized above.

crowd out not only ordinary public consumption, but also the collective good of the environment" (Bovenberg and de Mooij 1994).

The "Tax Interaction Effect"

To explain the apparent incongruity between a) a positive welfare gain from "revenue recycling" and b) an optimal environmental tax that is below marginal damage, the authors of the recent literature focus on changes in labor supply. They claim that when environmental taxes lower the real wage and labor supply, this narrows the tax base, producing a negative "tax interaction effect," and that this cost overshadows the "revenue recycling" or double dividend effect. According to this explanation, these effects cause the optimal environmental tax to be below MPD in the amenity case (Bovenberg and de Mooij 1994; Parry 1995; Bovenberg and Goulder 1997), and above MPD in the production externality case (Parry and Bento 1999, Williams 2000). This effect on labor supply is the same one that is described in stage 1, an effect that will be positive in the case of a production externality and negative in the case of an amenity externality.

One way to assess the importance of these "tax interaction effects" would be to compare results for two nearly-identical models, one with a production externality and one with an amenity externality. To do this, a pair of numerical models was calibrated to have identical labor supply elasticities (0.15), identical revenue requirements, and identical marginal social damages (0.216) affecting utility directly in one case and affecting labor productivity in the other)(Jaeger 2001b). Revenue requirements were set to generate marginal tax rates similar to those in the U.S. economy.[10] Based on the recent literature, we should expect a substantial divergence in the optimal environmental taxes for these two models due to the presence of a tax interaction cost in one case, and a tax interaction benefit in the other case.

Starting from this base case with uniform taxes, both models are allowed to select the optimal tax program. Labor supply rises in the case of the production externality and declines in the case of the amenity externality, as expected. How did these changes in labor supply affect the optimal environmental tax? The optimal environmental taxes for these two models differ only slightly: 0.322 in the production externality model, 0.317 in the amenity model. Moreover, in both models the environmental tax is above MSD: 49 percent above MSD in the production externality case, 46 percent above MSD in the amenity case. These slight differences are attributable to the changes in labor supply which affect the tax base and alter the parameters in (1). From this experiment, we conclude that these adjustments in labor supply have only a slight effect on the

[10] The GAMS code for each of these models is available from the author.

relationship between the optimal environmental tax and MSD—whether labor supply is increasing or decreasing.

If we compare the same optima and environmental taxes with the corresponding measures of MPD, a different picture emerges. In the production externality case, the environmental tax is 56 percent above MPD. In the amenity externality case, the optimal tax is 4 percent below MPD. As explained above, the large differences in this ratio are due to the divergence between MPD and MSD in the presence of revenue-motivated taxes, and the fact that MPD diverges in opposite directions for the two kinds of externalities. Nevertheless, if these differences are not recognized, comparisons of the optimal environmental tax with MPD would appear to indicate large swings in the optimal environmental tax, rather than large swings in MPD. Given that these changes in the ratio of t*/MPD are correlated with changes in labor supply, it is understandable how speculation about a causal story involving labor supply and excess burden might emerge in the face of these otherwise unexplained and incongruous changes in t*/MPD.

Conclusions

Early proponents of green tax reform believed that it held the promise of large, additional welfare increases when pollution tax revenues were used to finance reductions in preexisting taxes. The notion that we could tax "bads" instead of taxing "goods" certainly has some instinctive appeal. But the reality that pollution taxes must be paid out of the same income as preexisting taxes was not fully accounted for in some early analyses.[11] In one estimate, this oversight led to the conclusion that revenue recycling could raise the optimal carbon tax more than tenfold (Nordhaus 1993).

In contrast, opponents of the double dividend idea have relied on comparing the optimal environmental tax to a measure of marginal damages that does not reflect the social value of income. Basing their conclusions on the amenity externality case, they observed that the optimal environmental tax was lower than their measure of marginal damages even when environmental tax revenues were used to reduce revenue-motivated taxes. Efforts to explain this seemingly incongruous result led to speculation that a previously unrecognized "tax interaction effect" must be at work, and this theory was linked to changes in labor supply and the consequent narrowing of the tax base.

From the perspective presented here, a middle ground emerges. Very large additional benefits from green tax reform may not occur as a general rule. However, the optimal environmental tax *does* exceed marginal social damage, and it does so by 40 to 60 percent, a proportion that is remarkably consistent with the inference made initially by Pearce (1991).

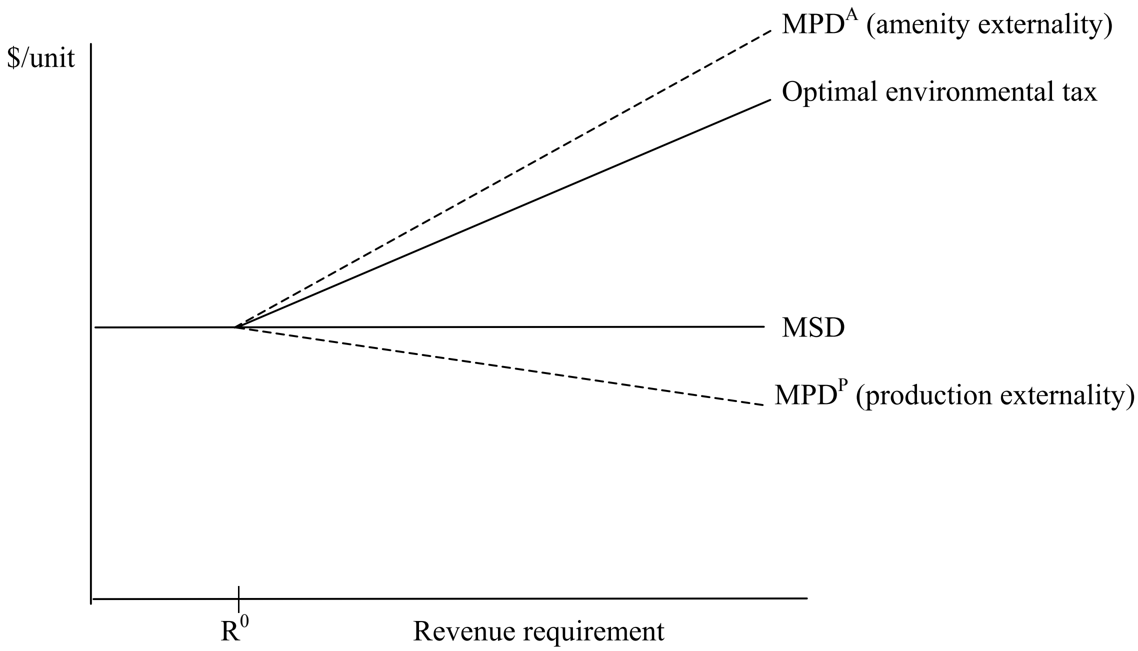
Is there an 'extra' benefit from green tax reform? Yes. Since the optimal environmental tax exceeds the social measure of marginal damages, and the optimal level of environmental quality rises with an increase in revenue requirements, we can infer that there is an additional welfare gain from green tax reform—indeed there is general agreement on this point.

Is there an extra cost to environmental policy? On balance, no. In the case of a production externality where the tax base is likely to broaden slightly, this will lower the excess burden of taxation. In the case of an amenity externality where the tax base is likely to narrow slightly, this will raise the excess burden of taxation. These effects are small and we have no *a priori* basis for expecting a positive or negative effect overall.

Do environmental goals compete with the provision of other public goods? No. The presence of revenue-raising taxes lowers the cost of environmental taxation and increases the level of environmental quality that can be achieved efficiently. Symmetrically, the existence of opportunities to tax pollution will lower the cost of raising revenues and, consistent with the Samuelson Condition, increase the optimal level of public goods provision.

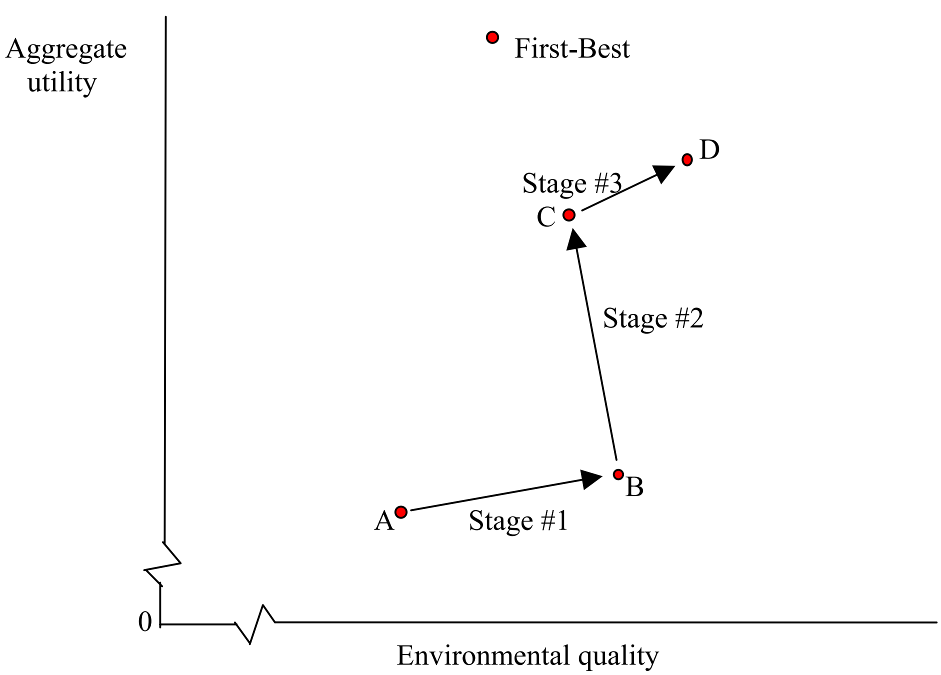
[11] See Fullerton and Metcalf (1997) for a critical survey of literature promoting the double dividend hypothesis.

Figure 1. The relationship between the optimal environmental tax and government's revenue requirement



Note: R^0 is the revenue requirement that could be satisfied by a Pigouvian tax.

Figure 2. Decomposition of the welfare and environmental effects of green tax reform.



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