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Ecological Tax Reforms and the Environment: A Note

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ECOLOGICAL TAX REFORMS AND THE ENVIRONMENT: A NOTE*

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ABSTRACT

There is widespread agreement on the ability of ecological tax reforms to improve the environmental quality. This paper, however, points out that a negative marginal impact on the environment cannot be ruled out for revenue-neutral ecological tax reforms in both first-best and second-best frameworks. Therefore, sufficient conditions are derived which ensure the improvement of the environmental quality.

I. INTRODUCTION

In recent years the double-dividend hypothesis has become very popular in both public finance and environmental economics. Ecological tax reforms that increase taxes on polluting goods, are expected to both improve the quality of the environment and to reduce the distortions of the existing tax system. While there is a controversy about the existence of the second dividend (cf., Bovenberg and de Mooij 1994, and Repetto 1994), there is widespread aggreement on the positive environmental impact of ecological tax reforms (cf., Goulder 1995).[1]

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[1] In the literature on the double dividend hypothesis, the environmental dividend is defined as the gross benefit arising from an improvement in the environmental quality (cf. Schöb 1996). Hence, although this paper does not

This note, however, points out that a negative impact on the environment cannot be ruled out for ecological taxes in general. Section II presents the model. Section III then shows that even in a first-best world an increase of the ecological tax, accompanied by a lump-sum rebate of tax revenues, does not necessarily improve the environment. In a second-best world the counterintuitive case of an ecolgical tax reform which deteriorates the environmental quality is even more likely to occur (Section IV). The paper, therefore, derives conditions which guarantee that the environmental impact of ecological tax reforms becomes positive.

II. THE MODEL

We ignore distributional issues by assuming that there are *H* identical households all treated equally by the government. Each household consumes three private goods 0, *c*, *d*. Good 0 (i.e. leisure) is chosen as numéraire and is assumed to be untaxed. The preferences of each household are described by a twice continously differentiable, strictly quasi-concave utility function. Assuming a small open economy, producer prices are equal to world market prices and remain constant when consumer prices change. This allows us to derive the demand functions for all good from the household's maximization behaviour:

$$x_i(t_c, t_d, T), \tag{1}$$

with $i = 0, c, d$. t_c denotes the tax rate on the clean good *c*, and t_d denotes the tax rate on the good *d*, called the dirty good. *T* is a lump-sum transfer from the government to the household. The transfer might be negative, in which case it is considered to be a lump-sum tax.

The consumption of the dirty good *d* creates a negative externality *E*. The externality (emissions) depends on the aggregate consumption of the dirty good:

$$E = e\left[Hx_d(t_c, t_d, T)\right], \tag{2}$$

with $\partial e/\partial x_d > 0$. Note that in this framework we assume that the consumption of all goods is independent of the level of emissions.

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provide a welfare analysis but focuses on changes in emissions, it should be noted that a reduction (increase) in emissions is always associated with a positive (negative) environmental dividend.

When analysing tax reforms we have to consider the budget constraint for the government. Defining R as the given tax requirement to provide a fixed amount of public goods, the budget constraint is given by

$$R = H \sum_{k=c,d} t_k x_k - HT. \tag{3}$$

The first term covers the tax revenues due to commodity taxation, the second term denotes the lump-sum transfers to the households. In what follows we focus on revenue-neutral tax reforms.

3. FIRST-BEST ANALYSIS

If there are no externalities and if the government can impose lump-sum taxes, any given public good provision is financed by lump-sum taxes only. In the presence of externalities, however, the government might use tax revenues from taxing the dirty good as well. Hence, the budget constraint in a first-best framework is given by

$$R = H(t_d x_d - T). \tag{3'}$$

Now consider a marginal ecological tax reform. Revenue neutrality requires:

$$dR = H\left[\left(x_d + t_d \frac{\partial x_d}{\partial t_d}\right) dt_d + \left(-1 + t_d \frac{\partial x_d}{\partial T}\right) dT\right] = 0. \tag{4}$$

The change in emissions can be derived from total differentiation of equation (2). Focussing on the change in emissions, we obtain the following condition:

$$dE \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Leftrightarrow \left(\frac{\partial x_d}{\partial t_d} dt_d + \frac{\partial x_d}{\partial T} dT\right) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0. \tag{5}$$ [2]

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[2] The consumption of the dirty good might depend on the emissions. In general, the demand function for the dirty good is given by $x_d^h = x_d^h(t_c, t_d, T, E)$. Implicit differentiation of (1) using (2) yields: $\partial E/\partial t_k = \frac{\partial E}{\partial x_d} \cdot H \cdot \frac{\partial x_d}{\partial t_k} \Big/ \left(1 - \frac{\partial E}{\partial x_d} H \cdot \frac{\partial x_d}{\partial E}\right)$. However, as long as an increase of emissions by one unit does not reduce the consumption of the dirty good by more than one unit, i.e. as long as the denominator is positive, the separability assumption does not change the results.

Solving equation (4) for dT and substituting in condition (5), we finally obtain:

$$\frac{dE}{dt_d}\begin{Bmatrix}>\\=\\<\end{Bmatrix}0 \Leftrightarrow \frac{s_{dd}}{1-t_d\,\dfrac{\partial x_d}{\partial T}}\begin{Bmatrix}>\\=\\<\end{Bmatrix}0\,, \qquad (6)$$

where $s_{dd} = \partial x_d / \partial t_d + x_d \cdot \partial x_d / \partial T$ denotes the compensated own-price effect which is negative. The denominator denotes the marginal revenue of lump-sum taxes. Hence, from condition (6) we can derive the following proposition:

Proposition 1 (First-best ecological tax reform): In a non-distorted tax system, a revenue-neutral ecological tax reform reduces (increases) emissions if marginal tax revenues from lump-sum taxes are positive (negative).

For d being a normal good $(\partial x_d / \partial T > 0)$, it turns out that a very high tax on d might lead to the case that even in the first-best world with lump-sum rebate of ecological tax revenues, an increase of the ecological tax might lead to an increase in emissions.

Figure 1 illustrates this extreme case. Assuming separability between private good consumption and emissions and an already very high tax on the polluting good, the households initial consumption bundle is given by P_0 which yields the household a sub-utility level of u_0. Now assume that a further increase of t_d reduces tax revenues, $\partial R/\partial t_d < 0$. Without changing other tax rates, the household would end up in P' (points above the iso-revenue line $dR = 0$ indicate a tax revenue shortfall). To meet the tax requirement ($dR = 0$), the government has to raise additional tax revenues. If, as a result of the high tax on the dirty good, the marginal tax revenues from lump-sum taxes are negative, $\partial R/\partial T > 0$, the government actually has to lower the lump-sum tax. This implies a shift of the (dotted) budget line to the right. As the new line is steeper, a solution tangent to the original indifference curve u_0 would still lead to a tax revenue shortfall. Therefore, the budget line has to shift further to the right, going beyond P_0, resulting in a higher consumption of the dirty good and higher emissions, respectively. Note that, in this case, the clean good is an inferior good.

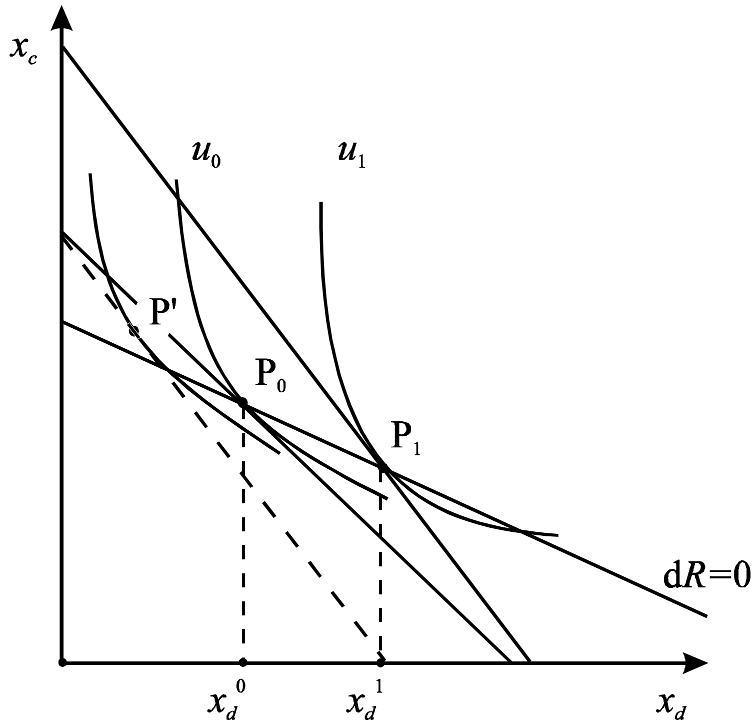

Figure 1

Private utility increases from u_0 to u_1 while the sub-utility from emissions decreases. If we continue to increase the tax on the dirty good, we will end up with an optimal tax which is equal to the marginal environmental damage, $t_d^* = -H(u_E/u_0)\cdot(\partial E/\partial x_d)$ (cf. Baumol and Oates 1988). For the case where, emissions actually increase, the Pigovian taxes exacly offset marginal losses in environmental quality by increasing private utility. This compensation scheme is the exact opposite of what is expected when looking at Pigovian taxes.

IV. SECOND-BEST ANALYSIS

As long as the government is not restricted in choosing the appropriate instruments, we can proceed in a first-best framework. However, the government normally does face some restrictions in using lump-sum taxes.[3] Assume that the government is not allowed to use lump-sum transfers. Instead, the government is forced to pay back the revenues from increasing the tax on the dirty good by reducing the tax rate on the clean good. In this case, the revenue-neutrality condition is given by

[3] This is a standard assumption in optimal taxation theory.

$$dR = \frac{\partial R}{\partial t_c} dt_c + \frac{\partial R}{\partial t_d} dt_d = H(x_c + \sum_{k=c,d} t_k \frac{\partial x_k}{\partial t_c}) dt_c + H(x_d + \sum_{k=c,d} t_k \frac{\partial x_k}{\partial t_d}) dt_d = 0. \tag{7}$$

The change in emission now becomes:

$$dE = H \frac{\partial E}{\partial x_d} \left(\frac{\partial x_d}{\partial t_c} dt_c + \frac{\partial x_d}{\partial t_d} dt_d \right). \tag{8}$$

Again, we are interested in the sign of the change in emissions. Assuming that both marginal tax revenues are positive, $\partial R / \partial t_k > 0$, it implies that for a revenue-neutral tax reform if $dt_d > 0$ then $dt_c < 0$. Using the revenue-neutrality condition (7), substitute for dt_c / dt_d into equation (8), we obtain

$$\left. \frac{dE}{dt_d} \right|_{dR=0} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Leftrightarrow \frac{\dfrac{\partial x_d}{\partial t_c}}{\dfrac{\partial x_d}{\partial t_d}} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \frac{\dfrac{\partial R}{\partial t_c}}{\dfrac{\partial R}{\partial t_d}}. \tag{9}$$

Emissions fall if, and only if, the ratio of the cross-price effect on the dirty good to the own-price effect of the dirty good is less than the ratio of the marginal tax revenues. However, if the dirty good is a substitute for the clean good, i.e. $\partial x_d / \partial t_c > 0$, the left-hand side will be negative and emissions will be reduced by both increasing the tax on the dirty good and reducing the tax on the substitute.[4]

In the case of a complementary relationship between the two taxed goods, i.e. $\partial x_d / \partial t_c < 0$, the change in emissions becomes ambigious. The environment improves if, and only if, the reduction in the consumption of the dirty good due to its own-price increase is higher than the increase due to the price reduction of the complement.

To see why emissions may actually increase, assume that the government increases the tax on the dirty good by one unit. If the marginal tax revenue $\partial R/\partial t_d$ is very high, the additional funds the government raises are large. These have to be refunded by reducing the tax on the clean good, $dt_c < 0$. If the marginal tax revenue of the clean good $\partial R/\partial t_c$ is relatively low compared to $\partial R/\partial t_d$, the clean good will be reduced at a high rate. As can be seen from (8), the ratio of

[4] In what follows all complementarity/substitutability relationships are uncompensated.

marginal tax revenues, $\partial R/\partial t_d/\partial R/\partial t_c$, is just the weight of the cross-price effect $\partial x_d/\partial t_c$. If the weight is large compared to the weight of the own-price effect (= 1), it might happen that, even in the case of a low cross price-effect, relative to the own-price effect, the increased consumption of the dirty good resulting from a reduction in t_c outweighs the reduction in consumption resulting from an increase in t_d. Hence, the existing tax system determines the effect a revenue-neutral ecological tax reform has on the environment. Proposition 2 summarises:

Proposition 2 (Second-best ecological tax reform): In a world with distortionary taxation, a revenue-neutral marginal ecological tax reform is reducing emissions, (*i*) if the accompanying tax reduction applies to a substitute for the dirty good or (*ii*) if it applies to a complement for the dirty good and the ratio of the cross-price effect on the dirty good to the own-price effect of the dirty good is smaller than the ratio of the associated marginal tax revenues.

Proposition 2 is related to the analysis of Ng (1980).[5] He looks at a revenue-neutral tax reform where the tax on the dirty good is increased and the tax on labour is decreased accordingly. He concludes that welfare will increase, "provided that an increase of the (consumer) price of the externality-producing good is more effective in reducing its consumption proportionately than is an increase in the (consumer) price of labor in increasing it, proportionately to labor" (p. 745). Thereby, he does not recognize that the effectiveness of price changes depends on the marginal tax revenues. (See his equation (15) and the following discussion of his results.) Instead, Ng abstracts "from the complication of a positive revenue requirement" (p. 747) when interpreting his result. Condition (9), however, shows that because of the revenue-neutrality condition, the marginal tax revenues actually determine the relative magnitudes of the tax rate changes and thus the 'relative effectiveness' of the price changes. It is the existing tax system the tax reform starts from, and the choice of the accompanying tax instruments, which determines the efficiency of ecological tax reforms to reduce emissions.

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[5] See also Schöb (1996).

V. CONCLUSION

When looking at ecological tax reform proposals it turns out that the change in the environmental quality depends on both the ecological tax and the accompanying measures the government takes to guarantee revenue neutrality. It is, therefore, the existing tax system an ecological tax reform starts from, which actually determines the efficiency of ecological tax reforms in achieving environmental targets.

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