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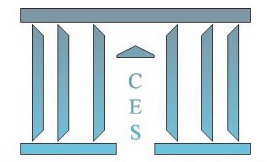

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Abstract

This paper analyzes the environmental tax policy issues within an overlapping generations models framework with heterogeneous workers. The objective is to analyze whether an environmental tax policy can respect the two equity principles simultaneously, the vertical as well as the horizontal one. We characterize the necessary conditions for the obtaining of a Pareto improving shift when the revenue of the pollution tax is recycled by a change in the labor tax rate or by a change in the distributive properties of the labor tax. We show that, depending on the production function elasticities and on the heterogeneity characteristics of labor supply, an appropriate policy mix could be designed in order to leave each workers' class unharmed by the environmental tax reform. It will consist in an increase of the progressivity of the labor tax together with a decrease of the minimal wage tax rate.

JEL classification: D60 - D62 - E62 - H23

Key words: Environmental tax - Overlapping generations model - Double dividend - Tax progressivity.

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1 Introduction

Environmental policies are an issue in which income class plays a significant role. First, the poor and the rich seem to assign different degrees of priority to environmental protection (Baumol and Oates [1]). This is quite intuitive since assuming environmental quality as a normal good, one would expect that wealthier individuals would want to buy more of it. Second, distributive elements also matter when we consider how the costs of a policy of environmental protection are likely to be distributed among individuals with differing incomes. This second point is of interest in a world in which inequality and poverty have assumed high priority among social issues. In addition, without adequate consideration of this aspect of the matter, we may not be able to design policies that can obtain the support they require for adoption. Thus, by ignoring the distributive effects of an environmental policy, we may unintentionally harm certain groups in society.

While positive net benefits from environmental policy imply that the gains have exceeded the losses for society as a whole, this may not be true for all members of society. Some segments of society may bear a disproportionate share of costs. Paying attention to environmental justice makes sense for two reasons, one ethical and the other pragmatic. The ethical dimension concerns whether the distribution of benefits and costs is in accordance with the norms of social justice. The desire for fair policies is a conventional complement to the desire for efficient policies. The pragmatic dimension emphasizes the relationship between the distributional burden and both the likelihood that environmental legislation will pass and its ultimate form. Policies and programs that are perceived as unfair will stand little prospect of passage even if they enhance the prospects for efficiency and sustainability. Identifying the sources of unfairness and restructuring programs to eliminate them increases the likelihood that otherwise desirable programs can proceed.

It is well known that the norms of social justice are not sufficiently well defined such that no norm is beyond reproach. Nonetheless, some conventional approaches have arisen that can serve to guide our inquiry. These involve two concepts known as horizontal and vertical equity.

Horizontal equity occurs when people with equal income are treated equally. With respect to pollution control, the principle of horizontal equity is satisfied if all persons with the same income receive the same net benefit. This principle can be used to assess the geographic and the racial fairness of policy. Vertical equity deals with the treatment of

unequals, or, using income as a basis, with the treatment of those with different income levels. The first step in assessing whether a particular policy satisfies vertical equity is to calculate how the net benefits are distributed among income groups: progressively, regressively or proportionally. A regressive allocation occurs only if the ratio of net benefit to income is larger for the rich than the poor. Hence, regressive policies violate the vertical equity principle.

Few studies have analyzed these concerns (Christiansen and Titienberg [7], Elliott et al. [9], Harrison [12], Peskins [18]) and most of them are empirical works dealing mainly with the distribution of benefits of the environmental policies among income classes, hence neglecting the cost side of the policies[1]. Moreover, most of the time, the only justice norm taken into account by these studies is the horizontal one.

The objective of this paper is to analyze whether an environmental tax policy can respect the two equity principles simultaneously, the vertical as well as the horizontal one. The framework is an overlapping generations model. Indeed, environmental decisions have an impact on the welfare of both current and future generations, since environmental quality is a public good that different generations share. These intergenerational issues on environmental externalities have already been studied in the economic literature (Howard and Norgaard [13]) but the overlapping generations approach began only to be used for analyzing environmental policies concerning polluting goods (John and Pecchenino[14], John et al. [15] or Bovenberg and Heidjra [2]). The main result of all these studies is that environmental policy implies such a welfare loss for the older generations experiencing the tax reform that its implementation can not be wished because the generation which would decide it would also bear the heaviest burden. Moreover, considering egoistic generations increases the intertemporal externalities. Consequently the central planner objectives are harder to achieve in the decentralized economy, requiring further economic instruments. We argue that the distributive properties of the tax policy could be one of the instruments of internalization of the intergenerational externalities.

We consider an overlapping generations economy with polluting production. Our model follows closely Chiroleu-Assouline and Fodha [5] and [6]. As in Chao and Peck [4] or Williams [20] or [21], we assume that the degradation of environmental quality has a

[1] In the French case, one can infer from some empirical studies emphasizing the regressivity of the indirect fiscality, and particularly when it bears on energy or transport consumption (like Ruiz and Trannoy [19]) that any environmental policy is likely to also be regressive.

negative impact on the total productivity of factors. This assumption is justified by the results of an increasing number of empirical studies measuring the links between pollution and health of workers (OCDE [16], Pervin et al. [17]) or between pollution and the quality of natural resources (Gollop and Swinand [10] for the agricultural sector). We assume that the production technology is a function of capital and heterogeneous labor. Heterogeneous workers live two periods (young and old) and earn heterogeneous wages corresponding to their skill and consequently to their productivity. The labor tax is a very general one that could be either a progressive, regressive or proportional tax. Our demographic assumptions allow us to take into account several income classes; indeed, we consider (i) the heterogeneity of the labor market (high wages - skilled workers, middle wages, low wages - non skilled workers...), (ii) the heterogeneity of the individual income source (wages for workers, savings for retired). The environmental policy consists of increasing the Pigovian tax on production. We then characterize the necessary conditions for the obtaining of a double dividend, i.e. an improvement of the environmental quality and an improvement of the welfare when the revenue of the pollution tax is recycled by a change in the labor tax rates. Previous studies show that the obtaining of a double dividend requires such economic conditions that the double dividend hypothesis seems unrealistic. Conversely, we show that when the budget-neutral tax reform requires a decrease of the labor tax rate, conditions may be defined to simultaneously allow (i) in the short term, an improvement of the welfare of both present generations; (ii) in the long term, the obtaining of a double dividend. These conditions lie on the distributive properties of the labor taxes.

2 The model

We consider an overlapping generations economy with polluting technology of production i.e. with polluting capital. Heterogeneous workers live two periods (young and old) and earn heterogeneous wages corresponding to their skill and consequently to their productivity. The labor tax is a very general one that could be either a progressive, regressive or proportional tax. We assume that N_t individuals are born in period t and that population remains constant, so we can normalize N_t to unity. Each household is characterized by its labor class (or skill) i and supplies one unit of labor[2] when she is young and earns a wage w_t; she divides her labor income between consumption and saving s_t. In the second period

[2] Our long term view allows us to assume full employment. Moreover we focus on efficiency double dividend (according to Goulder [11]) and not on employment double dividend.

the household consumes her saving and the interest she earns. $\frac{\eta}{1-\eta} \in [0,1]$ represents the individual intertemporal discount factor. The welfare of an individual born at t is measured with the intertemporal separable utility function :

$$U\left(c_t^{iy}, c_{t+1}^{io}\right) = (1-\eta)\ln c_t^{i,y} + \eta \ln c_{t+1}^{i,o}$$

with c_t^y denoting the first-period consumption of the agent born at t, c_{t+1}^o her second-period consumption. The two instantaneous components of the utility function obviously exhibit the usual properties: they are increasing in their argument, strictly concave and satisfy the Inada conditions. In order to unify the notations, we introduce straight away an index for the class of workers whom the household belongs (i).

The real interest rate is r_{t+1}. As the capital is polluting, the environmental policy consists in a Pigovian tax on savings τ^e. The household's budget constraints can be written as follows:

$$\begin{cases} \left(1-\tau^i\right) w_t^i = c_t^{iy} + \left(1+\tau_t^e\right) s_t^i \\ c_{t+1}^{io} = \left(1+r_{t+1}\right) s_t^i \end{cases} \tag{1}$$

The household's problem is to choose her consumption path to maximize her lifetime utility subject to the intertemporal budget constraint.

This yields the optimal consumption and saving path of the representative household, within the Diamond's framework (Diamond [8]) with a homothetic utility function:

$$\begin{cases} c_t^{iy} = (1-\eta)\left(1-\tau_t^i\right) w_t^i \\ c_{t+1}^{io} = \eta \dfrac{(1+r_{t+1})}{(1+\tau_t^e)}\left(1-\tau_t^i\right) w_t^i \\ s_t^i = \eta \dfrac{\left(1-\tau_t^i\right)}{(1+\tau_t^e)} w_t^i \end{cases} \tag{2}$$

The production sector consists of many firms, each of them being characterized by the same Cobb-Douglas production function F. They use different kinds of labor (high wages - skilled workers, middle wages, low wages - non skilled workers...) and the total productivity of factors $A(P_t)$ is negatively affected by pollution P_t because pollution deteriorates the health of workers or the quality of natural resources ($A'(P) < 0$ and $A''(P) = 0$ i.e. $A(P) = P^{-e}$ with $e > 0$):

$$Y_t = A(P_t) F(K_t, L_{i,t}) = A(P_t) K_t^{\lambda} \prod_{i=1}^{I} L_{i,t}^{\alpha_i}$$

where $\lambda > 0$ and $\alpha_i \geq 0$ stand for the shares of the input factors in production, $\lambda + \Sigma\alpha_i = 1$, $L_i = q_i.N$ and $\Sigma q_i = 1$.

The maximization problem of the representative firm is (taking the output price as numeraire):

$$\begin{aligned} \underset{K,\{L_i\}}{Max} \quad \pi_t &= Y_t - \sum_{i=1}^{I} w_t^i L_{i,t} - (1 + r_t) K_t \\ &= A(P_t) K_t^{\lambda} \prod_{i=1}^{I} L_{i,t}^{\alpha_i} - \sum_{i=1}^{I} w_t^i L_{i,t} - (1 + r_t) K_t \end{aligned}$$

with π_t the current net revenue, w_t^i the real wage rates. The depreciation rate of capital is null.

Since markets are competitive, capital and labor earn their marginal products:

$$\begin{cases} \dfrac{\lambda Y_t}{K_t} = 1 + r_t \\ \dfrac{\alpha_i Y_t}{L_{i,t}} = w_t^i \end{cases} \tag{3}$$

This yields, at the equilibrium of the labor markets (and with $N = 1$):

$$Y_t = A(P_t) F(K_t, L_{i,t}) = A(P_t) K_t^{\lambda} \prod_{i=1}^{I} q_i^{\alpha_i}$$

The ratio of wages is:

$$\frac{w_t^i}{w_t^1} = \frac{\dfrac{\alpha_i Y_t}{q_i}}{\dfrac{\alpha_1 Y_t}{q_1}} \iff w_t^i = \frac{\alpha_i}{\alpha_1} \frac{q_1}{q_i} w_t^1$$

We assume by now that the different labors are ordered by growing skills, i.e. by growing wages:

$$\begin{aligned} w_t^i &> w_t^{i-1} \\ \Leftrightarrow \quad \frac{\alpha_i}{q_i} &> \frac{\alpha_{i-1}}{q_{i-1}} \end{aligned}$$

We assume that government spending is entirely financed by current taxes. The government's budget constraint states that its purchases (G) must equal, at each period, its

tax revenues generated by the pollution tax and the labor tax:

$$\sum_{i=1}^{I} q_i \tau_t^i w_t^i + \tau_t^e \sum_{i=1}^{I} q_i s_t^i = G_t \tag{4}$$

We define a progressivity index of the labor tax, such as:

$$\tau^i = \tau^1 + a_i(a,i)$$

with $a_i \geq a_{i-1} \geq 1 \ \forall i > 1$ and $a_1 = a_1(a,1) = 0$, $a > 0$. Assume $\partial a_i(a,i)/\partial a \geqslant 0$; $\partial^2 a_i(a,i)/\partial a^2 = 0$; $\partial a_i(a,i)/\partial i \geqslant 0$; $\partial^2 a_i(a,i)/\partial i^2 \gtreqless 0$. We consider the general case for the characteristics of the tax progressivity (resp. regressivity if $\partial^2 a_i(a,i)/\partial i^2 < 0$). For example, the design of progressivity fits well the characteristics of the french tax system when $\partial^2 a_i(a,i)/\partial i^2 > 0$.

This yields

$$\sum_{i=1}^{I} q_i \tau^i w^i = \sum_{i=1}^{I} \tau^i \alpha_i Y = Y\left(\tau^1(1-\lambda) + \sum_{i=1}^{I} a_i(a,i)\alpha_i\right)$$

Assume $a_i(a,i) = a\,b(i)$ with $b(1) = 0$, $b' > 0$, $b'' \gtreqless 0$. We obtain:

$$\sum_{i=1}^{I} a_i(a,i)\alpha_i = a\sum_{i=1}^{I} b(i)\alpha_i = aB$$

let $B \equiv \sum_{i=1}^{I} b(i)\alpha_i > 0$ which is constant for any $I < \infty$.

The pollution flow is due to the capital, and we assume that the welfare is affected by the stock of pollution only through its effect on the global factor productivity. The dynamics of pollution is described by the following equation:

$$P_t = (1-h)P_{t-1} + \phi K_{t-1} \tag{5}$$

where h is the constant rate of natural absorption of pollution ($0 < h < 1$). At the steady-state equilibrium, the total stock of pollution is given by:

$$P^* = \frac{\phi}{h} K^*$$

The equilibrium condition of the capital market, meaning that the capital stock in period $t+1$ is the amount saved by young individuals in period t, is obtained by substituting

the zero-profit condition, the government's budget constraint (eq.4) and the household's budget constraints (eq.1) into the equilibrium of the output good market. It writes:

$$K_t = \sum_{i=1}^{I} q_i s_{t-1}^i = \frac{\eta}{1+\tau_{t-1}^e} \frac{q_1}{\alpha_1} \left(\left(1-\tau_{t-1}^1\right)(1-\lambda) - aB \right) w_{t-1}^1 \tag{6}$$

with $\dfrac{\alpha_1 Y_t}{q_1} = w_t^1$

Hence, at the steady-state equilibrium:

$$K^* = \frac{\eta}{1+\tau^e} \left[(1-\tau_1)(1-\lambda) - aB \right] Y^*$$

The equilibrium output and capital stock are solutions of the following system:

$$\begin{cases} K^* = \left\{ \dfrac{\eta}{1+\tau^e} \left[(1-\tau_1)(1-\lambda) - aB \right] A(P) \prod_{i=1}^{I} q_i^{\alpha_i} \right\}^{\frac{1}{1-\lambda}} \equiv K^* \left(\tau^e, \tau^1, a, A(P^*) \right) \\ Y^* = \left\{ \dfrac{\eta}{1+\tau^e} \left[(1-\tau_1)(1-\lambda) - aB \right] \right\}^{\frac{\lambda}{1-\lambda}} \left(A(P) \prod_{i=1}^{I} q_i^{\alpha_i} \right)^{\frac{1}{1-\lambda}} \equiv Y^* \left(\tau^e, \tau^1, a, A(P^*) \right) \end{cases} \tag{7}$$

Taking into account the specified pollution externality on the productivity:

$$\begin{cases} K^* = \left\{ \dfrac{\eta}{1+\tau^e} \left[(1-\tau_1)(1-\lambda) - aB \right] \right\}^{\frac{1}{1+e-\lambda}} \left[\left(\frac{\phi}{h} \right)^{-e} \prod_{i=1}^{I} q_i^{\alpha_i} \right]^{\frac{1}{1+e-\lambda}} \\ Y^* = \left\{ \dfrac{\eta}{1+\tau^e} \left[(1-\tau_1)(1-\lambda) - aB \right] \right\}^{\frac{\lambda-e}{1+e-\lambda}} \left[\left(\frac{\phi}{h} \right)^{-e} \prod_{i=1}^{I} q_i^{\alpha_i} \right]^{\frac{1}{1+e-\lambda}} \end{cases}$$

3 Welfare analysis

Like Chiroleu-Assouline and Fodha [6], we examine here the welfare effects of the tax change for a generation during its life-cycle, once the final steady-state equilibrium is reached. In this section, the welfare issue is thus a long term one.

One can measure the welfare effects of small tax changes by the marginal *excess burden*. This marginal excess burden corresponds to the additional income that needs to be provided to the representative household to keep her utility at its initial level: this is the *compensatory income variation*, denoted dR. It stands for the excess welfare loss of the consumers over and above the tax revenues collected by the government and can be interpreted as the hidden costs of financing public spending: a positive value for the marginal excess burden indicates a loss in welfare after the tax reform.

Let us determine the compensatory income variation which, after the tax reform, would leave the level of life-cycle utility unchanged ($dU = 0$):

$$\frac{\partial U}{\partial c^{iy}}\, dc^{iy} + \frac{\partial U}{\partial c^{io}}\, dc^{io} = 0$$

$$\Longleftrightarrow \frac{(1+r)}{(1+\tau^e)}\, dc^{y} + dc^{o} = 0$$

The intertemporal budget constraint of household i writes:

$$\left(1-\tau^i\right) w^i = c^{iy} + \frac{(1+\tau^e)}{(1+r)} c^{io}$$

Remember that

$$c^{io} = \frac{\eta}{(1-\eta)} \frac{(1+r)}{(1+\tau^e)} c^{iy}$$

We use the first-order conditions of the representative household's program and the definition of the compensatory income variation dR:

$$\begin{aligned}
\left(1-\tau^i\right) dw^i - w^i \left(d\tau^1 + b\,(i)\, da\right) + dR^i &= d\hat{c}^{iy} - \frac{\hat{c}^{io}}{(1+r)^2}\, dr + \frac{\hat{c}^{io}}{(1+r)} d\tau^e + \frac{(1+\tau^e)}{1+r} d\hat{c}^{io} \\
&= -\frac{(1+\tau^e)\,\hat{c}^{io}}{(1+r)^2}\, dr + \frac{\hat{c}^{io}}{(1+r)} d\tau^e
\end{aligned}$$

This leads to:

$$dR^i = -\left(1-\tau^i\right) dw^i + w^i \left(d\tau_1 + b\,(i)\, da\right) - \frac{(1+\tau^e)\,\hat{c}^{io}}{(1+r)^2}\, dr + \frac{\hat{c}^{io}}{(1+r)} d\tau^e \qquad (8)$$

Unlike Bovenberg and de Moiij [3] and the greater part of the literature on this subject, it is here impossible to distinguish an environmental component and a non-environmental one, because pollution and production affect each other. In this paper, we are thus constrained to depart from the usual definition of the double dividend (Goulder [11]) because of this non-separability: a double dividend will be characterized by the simultaneous decrease of pollution (which stands for the usual first dividend) and increase of economic welfare (which depends here also of the pollution level).

Proposition 1 *If $0 < \lambda - e < 1$, then we can find conditions to obtain $dK < 0$ and $dC > 0$ i.e. to obtain an environmental benefit and an increase of the global economic welfare.*

Proof. Notice first that the total effects on the output and on the capital stock of the tax reform are deduced from the total differentiation of eq. 7, we have

$$\begin{aligned} \frac{dY^*}{Y^*} &= -\frac{\lambda - e}{1-(\lambda-e)}\left[\frac{d\tau^e}{(1+\tau^e)} + \frac{(1-\lambda)\,d\tau^1 + Bda}{(1-\tau^1)(1-\lambda) - aB}\right] \\ \frac{dK^*}{K^*} &= -\frac{1}{1-(\lambda-e)}\left[\frac{d\tau^e}{(1+\tau^e)} + \frac{(1-\lambda)\,d\tau^1 + Bda}{(1-\tau^1)(1-\lambda) - aB}\right] \end{aligned} \tag{9}$$

Assume $\lambda - e > 0$. As pollution originates in the use of capital, we can achieve an environmental benefit if $\frac{dK^*}{K^*} < 0 \Leftrightarrow \frac{d\tau^e}{1+\tau^e} > -\frac{(1-\lambda)\,d\tau^1 + Bda}{(1-\tau^1)(1-\lambda) - aB}$.
And, as $Y = C + K + G$, we obtain $dC^* = dY^* - dK^* \geq 0 \Leftrightarrow |dY^*| < |dK^*| \Leftrightarrow \left|\frac{dY^*}{Y^*}\right| < \left|\frac{dK^*}{K^*}\right| \cdot \frac{Y^*}{K^*}$
$\Leftrightarrow (\lambda - e)\frac{Y^*}{K^*} < 1 \Leftrightarrow \frac{(\lambda - e)}{\frac{\eta}{1+\tau^e}((1-\tau_1)(1-\lambda) - aB)} < 1$. As $\frac{Y^*}{K^*} < 1$, $\lambda - e < 1$ is a sufficient condition (but not necessary) to obtain both dividends. ■

Corollary 2 *If $e > \lambda$, then we can find sufficient conditions to obtain $dK < 0$, $dY > 0$ and then $dC > 0$.*

Proposition 3 *The increase of the environmental tax is regressive i.e. it harms more heavily the lowest wages.*

Proof. Let us compute the steady-state value of the compensatory income variation for agent i:

$$\begin{aligned} \frac{dR^i}{\frac{\alpha_i}{q_i}Y^*} &= Z\frac{\left(1-\tau^i\right)}{(1+\tau^e)}d\tau^e \\ &+ \left[(Z-\eta)\frac{(1-\lambda)}{X} + \frac{1}{(1-\tau^i)}\right]\left(1-\tau^i\right)d\tau_1 \\ &+ \left[(Z-\eta)\frac{B}{X} + \frac{b\,(i)}{(1-\tau^i)}\right]\left(1-\tau^i\right)da \end{aligned} \tag{10}$$

with $Z = \frac{\lambda - e}{1-(\lambda-e)} > 0$ if $1 > \lambda - e > 0$ and $X = \left(1-\tau^1\right)(1-\lambda) - aB > 0$, constants.
Hence, when $d\tau^1 = da = 0$, one obtains, for any environmental tax increase $d\tau^e > 0$:

$$dR^i = \frac{\lambda - e}{1-(\lambda-e)}\frac{\left(1-\tau^i\right)}{(1+\tau^e)}\frac{\alpha_i}{q_i}Y^*d\tau^e$$

Notice that from the optimality conditions of the firm (eq. 3) and the equilibrium condition of the labor market, we have $\frac{\alpha_i}{q_i}Y^* = w_i$. We then have

$$\frac{dR^i}{w_i} = \frac{\lambda - e}{1-(\lambda-e)}\frac{\left(1-\tau^i\right)}{(1+\tau^e)}d\tau^e$$

then, if $\lambda - e > 0$, $dR^i > 0$ for every i. But $\frac{dR^i}{w_i}$ is less when (a) τ^i is higher, ie. i also high and (b) when w^i is higher. When the environmental policy harms the consumers, the relative burden is greater for the less skilled. ■

4 The specification of the balanced tax reform

We assume an exogenous increase of the pollution tax rate, imposed by the government in order to control pollution. The amount of government's purchases is assumed *ex post* invariant. This increase $d\tau^e$ of the pollution tax rate can be accompanied by a variation of the labor tax rates $d\tau^i$ by two potential means: an homogenous variation of all labor tax rates ($d\tau^1$) or a variation in the progressivity of the labor tax (da_i for $i > 1$ through a variation of a). At the steady state equilibrium, the government's budget constraint is:

$$\left(\tau^1(1-\lambda) + aB\right)Y + \tau^e K = G$$

The link between the variations of the pollution tax and the characteristics of the labor tax is obtained through the differentiation of this constraint, which is quite direct (using eq. 9).

Any balanced tax reform is then characterized by the following relationship between $d\tau^e$, $d\tau^1$ and da (with $dG = dq_i = d\alpha_i = 0$):

$$(1-\lambda)\,d\tau_1 + Bda = -\frac{(\eta+\Psi)}{(1+\Psi)}\frac{\left((1-\tau_1)(1-\lambda) - aB\right)}{1+\tau^e}d\tau^e$$

where $\Psi = -\left(\left(\tau_1(1-\lambda) + aB\right) + \frac{K}{Y}\frac{1}{(\lambda-e)}\tau^e\right)\frac{\lambda-e}{1-(\lambda-e)}\frac{1}{(1-\tau_1)(1-\lambda)-aB} \leq 0$ (if $\lambda - e > 0$) is constant.

Fiscal efficiency implies $\frac{(\eta+\Psi)}{(1+\Psi)}\frac{\left((1-\tau_1)(1-\lambda) - aB\right)}{1+\tau^e} > 0$[3].

We will study two polar cases for balancing this environmental tax reform:

[3] If $\lambda < e$ fiscal efficiency would always be verified.

- uniform variation of all labor tax rates (with invariant progressivity $da = 0$):

$$\Leftrightarrow d\tau^1 = -\frac{(\eta + \Psi)}{(1 + \Psi)} \frac{((1 - \tau_1)(1 - \lambda) - aB)}{1 + \tau^e} \frac{1}{(1 - \lambda)} d\tau^e = -\ \Lambda\ d\tau^e$$

- variation of the progressivity, with invariant labor tax rate for the low-skilled ($d\tau^1 = 0$):

$$\Leftrightarrow da = -\frac{(\eta + \Psi)}{(1 + \Psi)} \frac{((1 - \tau_1)(1 - \lambda) - aB)}{1 + \tau^e} \frac{1}{B} d\tau^e = -\ \Omega\ d\tau^e$$

Proposition 4 *The sign of the balanced tax reform multipliers* Λ *and* Ω *is a priori undetermined and depends on the initial tax rates and on the values of the various elasticities.*

Proof. (*i*) The numerator measures the effect of the change in pollution tax rate on its revenue. There are both a *value effect* (the tax revenue increases with the tax rate, for unchanged production) and a *tax base effect* (production decreases as the tax rate increases, thus the tax base erodes) which work in opposite ways. As a result, this term might be positive or negative.

(*ii*) The denominator measures the effect of the change in labor tax rate on its revenue. There are also both a *value effect* (the tax revenue increases with the tax rate, for unchanged wage) and a *tax base effect* (the wages decrease as the tax rate increases, thus the tax base erodes) which work in opposite ways. As a result, this term too might be positive or negative.

As the signs of the numerator and of the first and third terms of the denominator are undetermined, the sign of the necessary change in the labor tax is also undetermined. ■

5 The environmental effects of the tax reform

As steady-state pollution depends only on steady-state production per capita, we find straightforward that the first dividend (*ie.* a decrease of pollution) is reached if $dP^* = \frac{\phi}{h} dK^* < 0$. This condition rewrites (see eq. 9):

$$\frac{dK^*}{K^*} = -\frac{1}{1 - (\lambda - e)} \left[\frac{d\tau^e}{1 + \tau^e} + \frac{(1 - \lambda)\, d\tau^1 + B da}{(1 - \tau^1)(1 - \lambda) - aB} \right] < 0$$

Under the assumption $0 < \lambda - e < 1$, we have $1 - (\lambda - e) > 0$, which implies $\frac{d\tau^e}{1+\tau^e} + \frac{(1-\lambda)\, d\tau^1 + B da}{(1-\tau^1)(1-\lambda) - aB} > 0$. We then have the two cases corresponding to the two alternative policies:

- invariant progressivity $(da = 0) : \frac{d\tau^e}{1+\tau^e} > \frac{(1-\lambda)\,\Lambda d\tau^e}{(1-\tau^1)(1-\lambda) - aB}$
- variation of the progressivity $\left(d\tau^1 = 0\right) : \frac{d\tau^e}{1+\tau^e} > \frac{B\Omega d\tau^e}{(1-\tau^1)(1-\lambda) - aB}$.

We easily show that a sufficient condition for obtaining the environmental dividend is the negativity of the tax policy multipliers Λ or Ω. More generally, we obtain a first dividend if the multipliers are not too high:

$$\begin{cases} \Lambda < \dfrac{\left(1-\tau^1\right)(1-\lambda) - aB}{(1-\tau^e)(1-\lambda)} \\ \Omega < \dfrac{\left(1-\tau^1\right)(1-\lambda) - aB}{(1-\tau^e)\, B} \end{cases}$$

Observe that we do not need the Laffer-efficiency of the tax system as we can obtain the first dividend with imposing $d\tau^e > 0$.

6 The welfare effects of the tax reform

As each policy does not affect all classes equally, one can wonder which one will be preferred by each worker's class.

Proposition 5 *(i) The environmental tax reform preferred by the workers of the lowest classes consists of a decrease in the minimal wage tax rate τ^1 (ii) but the one preferred by the workers of the highest classes consists of a decrease in the progressivity of the wage tax rate.*

Proof. Let us compare the compensatory income variations associated to each policy.

- First case $(dR^i_{(\tau^1)})$: uniform variation of all labor tax rates (with invariant progressivity): $da = 0$ and $d\tau^1 = -\ \Lambda\ d\tau^e$

$$\begin{aligned} \frac{dR^i_{(\tau^1)}}{\frac{\alpha_i}{q_i} Y^*} &= \frac{\lambda - e}{1-(\lambda-e)} \frac{\left(1-\tau^i\right)}{(1+\tau^e)} d\tau^e \\ &\quad - \left[\frac{(Z-\eta)}{X} (1-\lambda) + \frac{1}{(1-\tau^i)} \right] \left(1-\tau^i\right) \Lambda\ d\tau^e \end{aligned}$$

- Second case ($dR^i_{(a)}$): variation of the progressivity, with invariant labor tax rate for the low-skilled: $d\tau^1 = 0$, $da_i = b(i)\, da$ and $da = -\ \Omega\ d\tau^e$

$$\begin{aligned}\frac{dR^i_{(a)}}{\frac{\alpha_i}{q_i}Y^*} &= \frac{\lambda - e}{1-(\lambda-e)}\frac{(1-\tau^i)}{(1+\tau^e)}d\tau^e \\ &\quad - \left[\frac{(Z-\eta)}{X}B + \frac{b(i)}{(1-\tau^i)}\right](1-\tau^i)\,\Omega d\tau^e\end{aligned}$$

The signs of these compensatory income variations depend on the values of the characteristics of the economy (λ, e, $b(i)$, α_i) and of the initial tax rates (τ^e, τ^i, a).

We now compare the relative effects on welfare of the two tax policies. Consequently, we have to determine the sign of $\Delta^i = \frac{\alpha_i}{q_i}Y^*\left[dR^i_{(a)} - dR^i_{(\tau^1)}\right]$ for the workers of class i.

$$\frac{\Delta^i}{(1-\tau^i)} = -\left[\frac{(Z-\eta)}{X}(1-\lambda) + \frac{1}{(1-\tau^i)}\right]\Lambda + \left[\frac{(Z-\eta)}{X}B + \frac{b(i)}{(1-\tau^i)}\right]\Omega \gtreqless 0$$

After some calculus, using $\frac{\Omega}{\Lambda} = \frac{1-\lambda}{B}$, we find that this sign is equal to the sign of:

$$b(i)\frac{1-\lambda}{B} - 1 = b(i)\frac{\Sigma\alpha_i}{\Sigma b(i)\,\alpha_i} - 1$$

There is one peculiar workers's class $\tilde{\imath}$ such that[4]:

$$b(\tilde{\imath}) = \frac{\Sigma_1^I b(i)\,\alpha_i}{\Sigma_1^I \alpha_i}$$

$b(\tilde{\imath})$ is the average of the coefficients of progressivity, weighted by the shares of each workers' class in the output. Each class of workers of a higher skill would prefer a decrease in the progressivity index and, at the contrary, each less skilled class of workers would prefer a decrease in the minimal rate of the wage tax (see Figure 1 corresponding to the French case of a progressive labor tax).

[4] Or, more precisely, $b(\tilde{\imath}) \geq \frac{\Sigma_1^I b(i)\alpha_i}{\Sigma_1^I \alpha_i}$ and $b(\tilde{\imath}-1) < \frac{\Sigma_1^I b(i)\alpha_i}{\Sigma_1^I \alpha_i}$.

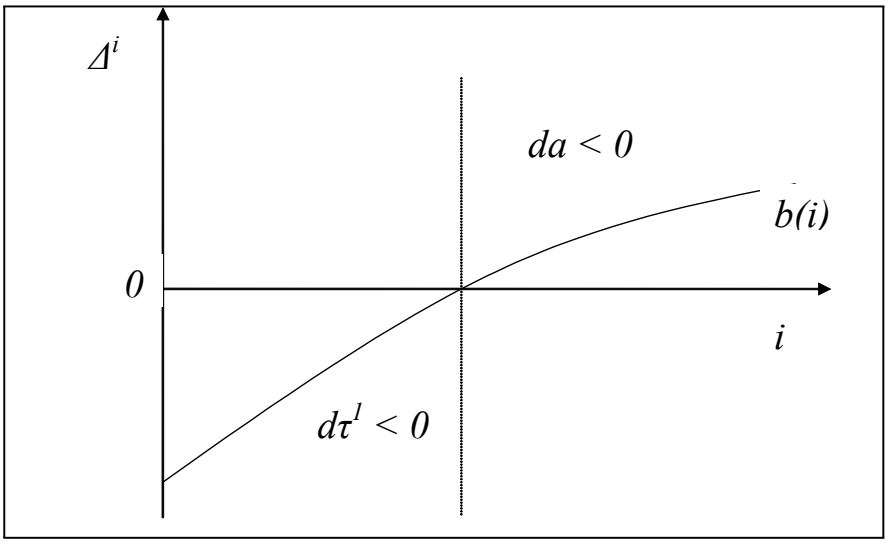

Figure 1: An illustration of workers's class threshold in the French case

■

The result above suggests that, in the case where some workers' classes would be suffering from a deterioration of their welfare after the above tax reforms, an appropriate policy mix could be designed in order to leave each workers' class unharmed by the environmental tax reform : it will consist in an increase of the progressivity index together with a decrease of the minimal wage tax rate.

Assume that the balanced tax reform is defined by $d\tau^1 < 0$ and $da = -\mu d\tau^1$ with $\mu > 0$ hence $da > 0$. Such a compensation of the increase in the environmental tax rate will imply a greater decrease of τ^1 than sooner because the degree of progressivity is raised.

Proposition 6 *For economies such that a decrease in the minimal wage rate doesn't suffice to reestablish the welfare of some workers' class, one can choose $\bar{\mu}$ in order to ensure that all classes will be better off with the environmental tax reform.*

Proof. Let us precise the link implied by such a policy between the increase in the environmental tax rate and the decrease in the minimal rate of the wage tax.

$$d\tau_e = -\frac{1}{\Lambda}d\tau^1 - \frac{1}{\Omega}da = -\frac{1}{\Omega}\left(\frac{\Omega}{\Lambda} - \mu\right)d\tau^1 = -\frac{1}{\Omega}\left(\frac{1-\lambda}{B} - \mu\right)d\tau^1$$

The compensatory income variation of the balanced mix policy is:

$$\begin{aligned}\frac{dR^i_{(3)}}{\frac{\alpha_i}{q_i}Y^*d\tau^e} &= \frac{\lambda-e}{1-(\lambda-e)}\frac{\left(1-\tau^1-ab\left(i\right)\right)}{\left(1+\tau^e\right)} \\ &\quad -\Lambda\left[\left(1-\tau^1-ab\left(i\right)\right)\left(Z-\eta\right)\frac{\left(1-\lambda\right)}{X}+1\right] \\ &\quad -\Lambda\left[\left(1-\tau^1-ab\left(i\right)\right)\left(Z-\eta\right)\frac{\left(1-\lambda\right)}{X}+b\left(i\right)\frac{1-\lambda}{B}\right]\mu \\ &= \frac{dR^i_{(\tau^1)}}{\frac{\alpha_i}{q_i}Y^*d\tau^e}-\Lambda\left[\left(1-\tau^1-ab\left(i\right)\right)\left(Z-\eta\right)\frac{\left(1-\lambda\right)}{X}+b\left(i\right)\frac{1-\lambda}{B}\right]\mu\end{aligned}$$

with $Z>0$, $X>0$, constants.

The sign of $Z-\eta$ depends on $(\lambda-e)$ and of the position of η relative to unity: $Z-\eta<0\Leftrightarrow(\lambda-e)<\dfrac{1}{\left(1+\frac{1}{\eta}\right)}<1$

- $dR^i_{(3)}\underset{\geq}{\overset{\leq}{\equiv}}0$, $\forall i=1,...I$.
- $dR^i_{(3)}$ is not monotonous in $b\left(i\right)$, nor in μ, $\forall i$.
- If $dR^i_{(\tau^1)}<0$, $\forall i=1,...I$, all classes will be better off even with $\mu=0$.
- If $\exists i, dR^i_{(\tau^1)}>0$, as the function $dR^i_{(3)}$ is bound, there is one $\bar{\imath}$ which maximizes it :

$$\bar{\imath}=\arg\max dR^i_{(3)}$$

One can choose $\bar{\mu}>0$ in order to nullify $dR^{\bar{\imath}}_{(3)}$: it ensures that all classes will be better off (their compensatory income variation are all negative or null).

$$\bar{\mu}=\frac{\frac{\lambda-e}{1-(\lambda-e)}\frac{\left(1-\tau^1-ab\left(\bar{\imath}\right)\right)}{\left(1+\tau^e\right)}-\Lambda\left[\left(1-\tau^1-ab\left(\bar{\imath}\right)\right)\left(Z-\eta\right)\frac{(1-\lambda)}{X}+1\right]}{\Lambda\left[\left(1-\tau^1-ab\left(\bar{\imath}\right)\right)\left(Z-\eta\right)\frac{(1-\lambda)}{X}+b\left(\bar{\imath}\right)\frac{1-\lambda}{B}\right]}$$

■

7 Conclusion

In this paper, we have shown that a budget-neutral environmental tax reform may result in a double dividend (defined as a decrease in pollution and an increase in the global

economic welfare), even when the economy is characterized by heterogenous agents (old and young) and many worker classes (heterogenous labor). We have also emphasized that the conditions for the obtaining of a double dividend lie on the distributive properties of the labor taxes. Even when the double dividend is not possible, the cost of the pollution regulation can be minimized by a new designing of the progressivity of the labor tax instead of an homogenous cut in the labor tax rates. We conclude that the distributive properties of the tax policy could be one of the instruments of internalization of the intergenerational externalities.

Our paper underlines the gap between economic efficiency and vertical equity and illustrates the problem of the aggregation of positive and negative compensatory variations: the usual way of aggregation gives a higher weight to the wealthiest classes and introduces a bias when assessing the desirability or the acceptability of any environmental tax reform.

References

[1] W.J. Baumol and W.E. Oates, "The Theory of Environmental Policy", Cambridge University Press, 2nd edition, (1988).

[2] A.L. Bovenberg and B.J. Heidjra, Environmental Tax Policy and Intergenerational Distribution, *Journal of Public Economics*, **67**, 1-24 (1998).

[3] A.L. Bovenberg and R.A. de Mooij, Environmental Levies and Distortionary Taxation, *American Economic Review*, **84** (4), 1085-1089 (1994).

[4] H.-p. Chao and S. Peck, Greenhouse Gas Abatement: How Much? and Who Pays?, *Resource and Energy Economics*, **22**, 1-20 (2000).

[5] M. Chiroleu-Assouline and M. Fodha, Double Dividend with Involuntary Unemployment: Efficiency and Intergenerational Equity, *Environmental and Resource Economics*, **31**(4), 389-403 (2005).

[6] M. Chiroleu-Assouline and M. Fodha, Double Dividend Hypothesis, Golden Rule and Welfare Distribution, *Journal of Environmental Economics and Management*, **51**(3), 323-335 (2006).

[7] GB. Christiansen and TH. Titienberg, Distributional and Macroeconomic Aspects of Environmental Policy, in A Kneese and J. Sweeney, eds. "Handbook of Natural Resource and Energy Economics", Amsterdam, (1985).

[8] P.A. Diamond, National Debt in a Neoclassical Model, *American Economic Review*, **55**, 1126-1250 (1965).

[9] DB. Elliott and JC. Millian, Toward a Theory of Statutory Evolution: The federalization of Environmental Law, *Journal of Law, Economics, and Organization*, 313-340 (1985).

[10] F.M. Gollop and G.P. Swinand, From Total Factor to Total Resource Productivity: An Application to Agriculture, *American Journal of Agricultural Economics,* **80**, 577-583 (1998).

[11] L.H. Goulder, Environmental Taxation and the "Double Dividend": A Reader's Guide, *International Tax and Public Finance,* **2**, 157-183 (1995).

[12] D. Jr. Harrison, The Distributive Effects of Economic Instruments for Environmental Policy, Paris, OECD, (1994).

[13] R.B. Howarth and R.B. Norgaard, Intergenerational Choices Under Global Environmental Change, in "The Handbook of environmental economics" (D.W. Bromley, Ed.), Blackwell Handbooks in Economics, 111-138 (1995).

[14] A. John and R. Pecchenino, An Overlapping Generations Model of Growth and the Environment, *The Economic Journal*, **104**, 1393-1410 (1994).

[15] A. John, R. Pecchenino, D. Schimmelpfennig and S. Schreft, Short-Lived Agents and the Long-Lived Environment, *Journal of Public Economics*, **58**, 127-141 (1995).

[16] OECD, Costs of Inaction on Key Environmental Challenges, Paris, (2008).

[17] T. Pervin, U.-G. Gerdtham and C.Hampus Lytkens, Societal Costs of Air Pollution-Related Health Hazards: A Review of Methods and Results, *Cost Effectiveness and Resource Allocation*, **6** (19), (2008).

[18] H. Peskins, Environmental Policy and the Distribution of Benefits and Costs, in R. Portney, ed. "Current Issues in U.S. Environmental Policy", J. Hopkins University Press for Resources for the Future, (1978).

[19] N. Ruiz and A. Trannoy, Le caractère régressif des taxes indirectes : les enseignements d'un modèle de microsimulation, *Economie et Statistique*, **413**, 21-46 (2008).

[20] R.C. Williams III, Environmental Tax Interactions when Pollution Affects Health or Productivity, *Journal of Environmental Economics and Management*, **44**, 261-270 (2002).

[21] R.C. Williams III, , Health Effects and Optimal Environmental Taxes, *Journal of Public Economics*, **87**(2), 323-335 (2003).