Environmental Tax and the Distribution of Income with Heterogeneous Workers

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Abstract

This paper analyzes the environmental tax policy issues when labor is heterogeneous. The objective is to assess whether an environmental tax policy could be Pareto improving, 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 consists 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 - Intergenerational equity- Double dividend.

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Abstract: This paper analyzes the environmental tax policy issues when labor is heterogeneous. The objective is to assess whether an environmental tax policy could be Pareto improving, when the revenue of the pollution tax is recycled by a change in the labor tax properties. We show that, depending on the production technology and on the heterogeneity characteristics of labor, a policy mix could be designed in order to leave each workers' class unharmed. It consists in an increase of the progressivity together with a decrease of the minimal wage tax rate.

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1 Introduction

The costs and benefits of the environmental policies are unequally distributed among agents. The poor and the rich seem to assign different degrees of priority to environmental protection (Baumol and Oates [1]), since wealthier individuals would accept to pay for a higher level of environmental quality (considered as a normal good). Beyond this fact, 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. Most of existing studies are empirical works dealing mainly with the distribution of benefits of the environmental policies among income classes (Christiansen and Titienberg [8], Elliott et al. [10], Harrison [13], Peskins [18]), hence neglecting the cost side of the policies. One can infer from some empirical studies emphasizing the regressivity of the indirect taxes, that any environmental policy is likely to also be regressive. In particular, for the French case, a tax bearing on energy or transport consumption harms the lowest wage households three times more heavily than the highest wage ones (Ruiz and Trannoy [19]). Moreover, the usual recycling of the environmental tax revenues through a decrease in the labor tax rate could be also regressive. This point is of interest in a world in which inequality has assumed high priority among social issues. The objective of this paper is therefore to design a balanced environmental tax reform able to correct these regressive properties and to leave any workers class better off.

We consider an overlapping generations economy with polluting capital. Our model shares the mean features of Chiroleu-Assouline and Fodha [6] and [7]. As in Chao and Peck [5] or Williams [21] or [22], we assume that the degradation of environmental quality has a negative impact on the total productivity of factors. This assumption is justified by the results of an increasing number of empirical studies measuring the health effects of pollution (OCDE [15]) and the impact of the health of workers on labor productivity (Bloom et al. [2], in a sample consisting of both developing and industrial countries, found that good health, proxied by life expectancy, has a sizable, positive effect on economic growth). Since Ostro [16], many papers emphasize the loss of productivity caused by the health effects of pollution, e.g. Samakovlis et al. [20], or Pervin et al. [17] for air-pollution, and also Bosello et al. [3] or Hübler et al. [14] for the health effects of climate change. For example, according to Bosello et al. [3] strong heat stress causes a productivity loss of 3% and extreme heat a loss of 12%. Another source of productivity loss originates in the impact of pollution on the quality of natural resources (Gollop and Swinand [11] 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 savings. 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 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 environmental externalities.

The paper is organized as follows. Section 2 presents the model and section 3 presents the welfare analysis of a tax policy. Section 4 gives the specification of the balanced tax reform. In section 5, we present the environmental effects of the tax reform and section 6 examines the welfare effects of such a reform. The last section concludes.

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[1] 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 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[2] :

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

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.

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:

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

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 [9]) with a homothetic utility function:

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

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

[1] Our long term view allows us to assume full employment. Moreover we focus on efficiency double dividend (according to Goulder [12]) and not on employment double dividend.

[2] We do not introduce any direct effect of pollution on the households welfare, but only the indirect one through the consequences on productivity of the degradation of environmental quality. Indeed the direct effect would have no impact on the welfare distribution among heterogenous agents while the indirect one affects the wage gaps.

health of workers or the quality of natural resources ($A'(P) < 0$ and $A''(P) \geq 0$ 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 equal to unity.

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:

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

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:

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

where τ^1 is the minimal wage tax rate, $a_i \geq a_{i-1} \geq 1 \; \forall i > 1$ 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 $a_i (a, i) = ab (i)$ 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:

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

As for now, assume for realism that $0 < e < \lambda$ which means that the direct contribution of capital to output is greater than the indirect one through pollution and productivity[3].

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:

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

with $X = \left(1-\tau^1\right)(1-\lambda) - aB > 0$, constant for a given tax system .

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

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

Taking into account the specified pollution externality on the productivity:

$$\begin{cases} K^* = \left\{\dfrac{\eta}{1+\tau^e} X\right\}^{\frac{1}{1-(\lambda-e)}} \left[\left(\dfrac{\phi}{h}\right)^{-e} \prod_{i=1}^{I} q_i^{\alpha_i}\right]^{\frac{1}{1-(\lambda-e)}} \\ Y^* = \left\{\dfrac{\eta}{1+\tau^e} X\right\}^{\frac{\lambda-e}{1-(\lambda-e)}} \left[\left(\dfrac{\phi}{h}\right)^{-e} \prod_{i=1}^{I} q_i^{\alpha_i}\right]^{\frac{1}{1-(\lambda-e)}} \end{cases} \tag{8}$$

[3] Assuming the contrary ($\lambda < e$) would simplify the analysis but this case would be of negligible economic interest because any rise in τ^e would result in a decrease of K allowing an increase of Y.

3 Welfare analysis

Like Chiroleu-Assouline and Fodha [7], 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:

$$dR^i = -\left(1-\tau^i\right) dw^i + w^i \left(d\tau^1 + b\,(i)\, da\right) - \frac{(1+\tau^e)\,\hat{c}^{io}}{(1+r)^2}\, dr + \frac{\hat{c}^{io}}{(1+r)} d\tau^e \qquad (9)$$

Unlike Bovenberg and de Moiij [4] 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 [12]) 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 *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:

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

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

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

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

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

then, as $\lambda-e>0$, $dR^i>0$ for every i. But $\dfrac{dR^i}{w_i}$ is smaller when τ^i is higher (i.e. i also high) and 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. 8).

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

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

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

Fiscal efficiency implies $\frac{(\eta + \Psi)}{(1+\Psi)}\frac{X}{1+\tau^e} > 0$[4].

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

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

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

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

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

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

Proposition 2 *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 (*i.e.* a decrease of pollution) is reached if $dP^* = \frac{\phi}{h} dK^* < 0$. This condition rewrites:

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

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

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

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:

$$\begin{cases} \Lambda < \dfrac{X}{(1+\tau^e)(1-\lambda)} \\ \Omega < \dfrac{X}{(1+\tau^e)B} \end{cases}$$

This means that the decrease of the labor tax (either of the minimal wage tax rate or of the progressivity index) should be not too strong in order to not jeopardize the environmental benefit of the reform.

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 3 (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 $d\tau^1 = -\ \Lambda\ d\tau^e$

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

- 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 $da = -\ \Omega\ d\tau^e$

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

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 $\Delta^i = \frac{\alpha_i}{q_i} Y^* \left[dR^i_{(\tau^1)} - dR^i_{(a)} \right]$ for the workers of class i.

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

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[5]:

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

$b(\tilde{\imath})$ 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, $da < 0$, and, at the contrary, each less skilled class of workers would prefer a decrease in the minimal rate of the wage tax, $d\tau^1 < 0$ (Figure 1 corresponding to the French case of a progressive labor tax). ■

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.

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

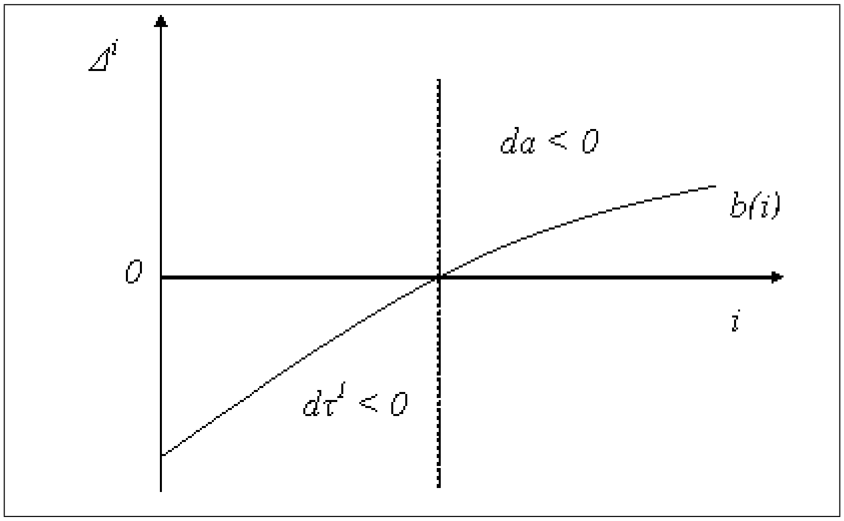

Figure 1: An illustration of workers's class threshold in the French case

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 above because the degree of progressivity is raised.

Proposition 4 *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:

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

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

- $dR^i_{(\mu)} \lesseqgtr 0$, $\forall i = 1, ...I$.
- $dR^i_{(\mu)}$ is not monotonous in $b(i)$, 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 $dR^i_{(\mu)}$ is bound, there is one $\bar{\imath}$ which maximizes it:

$$\bar{\imath} = \text{INT}\left[\arg\max dR^i_{(\mu)}\right]$$

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

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

■

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.

To a certain extent, 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] D.E. Bloom, D. Canning and J. Sevilla, The Effects of Health on Economic Growth: A Production Function Approach, *World Development*, **32**, 1-13 (2004).

[3] F. Bosello, R. Roson and R.S.J. Tol, Economy-wide Estimates of the Implications of Climate Change: Human Health, *Ecological Economics*, **58**, 579-581 (2006).

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

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

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

[7] 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).

[8] 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).

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

[10] 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).

[11] 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).

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

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

[14] M. Hübler, G. Klepper and S. Peterson, Costs of Climate Change - The Effects of Rising Temperatures on Health and Productivity, *Ecological Economics*, **68**, 381-393 (2008).

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

[16] B.D. Ostro, The Effects of Air Pollution on Work Loss and Morbidity, *Journal of Environmental Economics and Management*, **10**, 371–382, (1983).

[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] E. Samakovlis, A. Huhtala, T. Bellander and M. Svartengren, Valuing Health Effects of Air Pollution - Focus on Concentration-response Functions, *Journal of Urban Economics*, **58**, 230-249 (2005).

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

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