Political sustainability and the design of environmental taxes*

Helmuth Cremer
University of Toulouse
(IDEI and GREMAQ)

Philippe De Donder†
University of Toulouse
(IDEI and GREMAQ)

Firouz Gahvari
Department of Economics
University of Illinois at Urbana-Champaign

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Abstract

This paper studies the issue of political support for environmental taxes. The environmental tax is determined by majority voting, given a refund rule that specifies the allocation of tax proceeds. The refund rule is chosen by a welfare-maximizing constitutional planner. We show that: (i) The equilibrium tax rate is increasing in the proportion of tax reductions based on wage incomes. (ii) If labor and capital income taxes are reduced in the same proportion, to keep the government's budget balanced, majority voting yields a rate of environmental taxation that is lower than the optimal (Pigouvian) level. (iii) To mitigate this negative bias, the government reduces wage taxes by a higher proportion than capital income taxes. (iv) The final outcome will either be the Pigouvian tax or else all reductions will be given in wage taxes. This depends on individuals' preferences for the polluting good as well as wage and capital income distributions.

Key words: Environmental taxes, Pigouvian tax, political support, majority voting.

JEL Classification: H23, D72.

1 Introduction

The design of environmental policies has assumed a more urgent tone in recent years. In part, this reflects the continued interest of the general public and the mass media in environmental issues. One important aspect of the design problem is its "political feasibility". The adoption of any particular environmental policy, whether taxation, quotas or tradeable permits, is, at least in the industrialized countries, subject to its passage through a complex political process. This is all the more contentious because such policies invariably entail losers and winners. Consequently, policy makers are subject to a considerable amount of political pressure so much so that even a well-informed and benevolent government may not be able to implement an otherwise optimal policy. The role of the political process in arriving at a particular policy must thus be explicitly recognized and studied.

The economics literature has thus far studied environmental policies mainly from a welfare economics perspective. In particular, it has, over the past two decades, examined the impact and the design of policies in various second-best settings.[1] Political economy considerations have been introduced only very recently and by few authors; see e.g. Bös (2000), Brett and Keen (2000), Marsiliani and Renström (2000), and Boyer and Laffont (1998). This is rather surprising for the impact of political process has been extensively studied for other areas of government intervention.[2]

This paper examines the issue of political support for environmental taxes. We are particularly interested in the properties of environmental taxes that must have the backing of the voters. Specifically, we have in mind environmental taxes levied to combat CO_2 emissions, from fossil-fuel combustion, deemed to be the most important of greenhouse gases. Are such taxes set at efficient levels? If not, are there supporting mechanisms

[1] See e.g., Sandmo (1975), Bovenberg and van der Ploeg (1994) or, more recently, Cremer *et al.* (1998) and Cremer and Gahvari (2001).

[2] A recent application is in the area of social insurance; see, e.g. Casamatta *et al.* (2000), and De Donder and Hindriks (1998). Regulatory policies are considered by Laffont (1996).

that may restore efficiency, or at least mitigate the extent of the inefficiency? In addressing these questions, we shall assume that environmental taxes are determined through majority voting. Moreover, to make these taxes more agreeable, we assume that their proceeds will be refunded to taxpayers. We further assume that the "refund rule" is determined prior to the tax rate by a welfare maximizing authority who anticipates the induced voting equilibrium. This analysis combines normative and positive features.[3] The main lesson that emerges is that the refund rule plays a crucial role in determining the political support for environmental taxation. In particular, the rule can be manipulated to induce a more desired outcome.

Our analysis is based on an economy where individuals derive income from capital and labor, a higher income level is associated with a higher *share* of capital income, and the median income is less than average income. The proceeds of a tax on a polluting good are rebated through reductions of taxes on labor and/or capital incomes. The refund rule specifies the proportion of tax proceeds that must be refunded on the basis of labor incomes.

We show that if labor and capital taxes are reduced in the same proportion (e.g. proceeds are used to reduce a tax on global income), then majority voting yields a rate of environmental taxation which is lower than the optimal (Pigouvian) level. The (constitutional) planner will always be able to mitigate this negative bias by refunding a higher proportion on labor incomes than on capital incomes. It will either totally eliminate the bias, or else will base all the refunds on labor incomes. Which outcome would prevail depends on individuals' preferences for the polluting good as well as wage and capital income distributions.

Finally, our analysis sheds some new light on the so called double divi-

[3]In a companion paper, Cremer *et al.* (2004), we adopt a completely positive approach. There, we also study the properties of environmental taxes and refund rule assuming different voting mechanisms, including simultaneous voting, sequential voting and the Shepsle procedure.

dend hypothesis. This theory suggests that the recycling of tax revenues (in particular through reduction in taxes on labor income) is a crucial ingredient of environmental tax policy. We argue that the significance of this aspect is not necessarily linked to the reduction of distortions associated with the pre-existing taxes. Instead, it plays an important role in ensuring political support for a policy which otherwise would be infeasible. Specifically, the political support argument may call for a refund through reductions in labor taxes.

2 The model

2.1 Setting

Individuals are identified by a parameter θ which is continuously distributed over $[0,1]$ according to the density function, $f(\theta)$. The associated cumulative distribution function is $F(\theta)$. Population size is normalized at one. An individual of type θ has a total income of $m(\theta)$, with

$$m(\theta) = w(\theta) + r(\theta),$$

where $w(\theta)$ is labor and $r(\theta)$ is capital income. All sources of income are exogenous and individuals are ranked such that $m'(\theta) > 0$, i.e., total income increases with θ. Let $\overline{r}$, $\overline{w}$ and $\overline{m}$ denote average capital, labor and total incomes:

$$\overline{r} = \int_0^1 r(\theta)f(\theta)d\theta, \quad \overline{w} = \int_0^1 w(\theta)f(\theta)d\theta, \quad \overline{m} = \int_0^1 m(\theta)f(\theta)d\theta.$$

Let $\widehat{\theta}$ be the median individual (satisfying $F(\widehat{\theta}) = 1/2$), and denote his capital, wage and total income by $\widehat{r} \equiv r(\widehat{\theta})$, $\widehat{w} \equiv w(\widehat{\theta})$, and $\widehat{m} \equiv m(\widehat{\theta})$. Throughout the paper, we shall assume that the distributions of incomes satisfy:

Assumption 1 *Wage and capital incomes satisfy the following properties:*

(i) $w'(\theta) > 0$, $r'(\theta) > 0$,

(ii) $r(\theta)/w(\theta)$ *increases with* θ,

(iii) $\widehat{r}/\overline{r} < \widehat{w}/\overline{w} < 1$ *so that* $\widehat{m} < \overline{m}$.

Assumptions (i)–(ii) tell us that a higher θ corresponds to higher levels of both capital and labor incomes, and to a larger share of capital income. Assumption (iii) reflects the stylized fact that median income (capital and labor as well as total) is typically less than average income. It further stipulates that the ratio of median to average income is larger for labor than for capital income. This captures the fact that the distribution of capital income is typically more asymmetric than labor income, with a small number of individuals having very high capital income levels.[4]

All individuals have identical Gorman-polar form preferences over a numeraire good (non-polluting), a polluting good, y, and *total* level of emissions in the atmosphere, a negative consumption externality, Y. One may think of "the polluting good" as a composite good consisting of all energy-related goods whose consumption (and production) emit CO_2 and contribute to global warming. The choice of Gorman-polar preferences is based on empirical evidence for the income elasticity of such goods. Poterba (1991) has estimated that the expenditure shares of such polluting goods as gasoline, fuel oil, natural gas and electricity decrease, with very few exceptions, at all income deciles as income increases.

The goods are produced by a linear technology subject to constant returns to scale in a competitive environment. Normalize the producer price of y at one. Let q denote the consumer price of y, $I(\theta)$ the disposable income (net of taxes or transfers) and Y the total consumption of y (across all individuals). The indirect utility function of an individual of type θ is given by:

$$v(q, I, Y) = a(q) + b(q)I(\theta) - \varphi(Y), \tag{1}$$

[4]Using the PSID family income for year 2000, we obtain based on 6,877 observations, $\widehat{r}/\overline{r} = 0.04 < \widehat{w}/\overline{w} = 0.72 < 1$.

where $a(q)$ is thrice and $b(q)$ and $\varphi(Y)$ are twice continuously differentiable with $a'(q) \leq 0$, $b'(q) \leq 0$, $\varphi'(Y) > 0$, and $\varphi''(Y) \geq 0$. Observe that, ignoring the externality term, $b'(q) \equiv 0$ yields a quasi-linear specification; on the other hand, $a(q) \equiv 0$ represents the case of homothetic preferences. By Roy's identity, the demand for y is given by[5]

$$y(q;\theta) = -\frac{\partial v/\partial q}{\partial v/\partial I} = c(q) + d(q)I(\theta), \tag{2}$$

where

$$c(q) = \frac{-a'(q)}{b(q)} > 0, \quad \text{and} \quad d(q) = \frac{-b'(q)}{b(q)} > 0.$$

Aggregate consumption of the polluting good is equal to

$$Y = \int_0^1 y(q;\theta)f(\theta)d\theta = \overline{y}(q), \tag{3}$$

so that total and average consumption levels are equal. Observe that the variation in a *single* individual's consumption of y will have no impact on Y.

The existing tax structure consists of labor and capital income taxes. Good y is to be subjected to a "pollution tax" levied at the rate of $(q-1)$ per unit of output. The proceeds of the tax are refunded through reductions in labor and capital income taxes. To simplify notation, we do not include pre-existing income taxes explicitly. This implies that the net of tax income of individual θ is given by

$$I(\theta) = (1 + g_r)r(\theta) + (1 + g_w)w(\theta), \tag{4}$$

where $g_r \geq 0$ and $g_w \geq 0$ are the refund rates on capital and wage income taxes.[6] Note that constraining the tax structure to consist only of labor and capital income taxes implies that there will be no uniform lump-sum refunds. Allowing for uniform lump-sum taxation, yields the trivial result

[5]We are assuming that $I(\theta)$ is "sufficiently large" for all types so that their consumption of the numeraire good is also positive.

[6]This rules out the "possibility" that one may want to subsidize y rather than tax it. Such an outcome can arise if the marginal social damage of emissions is very small.

that the government is always able to achieve a first-best outcome using this instrument. However, this outcome is an artifact of our two other simplifying assumptions, namely, that wage and capital income taxes are non-distortionary and preferences are homogeneous. These features are plainly absent in a more complex world which renders lump-sum taxation either infeasible (if it is to be differential) or undesirable (if it is to be uniform).[7]

Denote the government tax revenues by $R(q)$ where

$$R(q) = (q-1)\overline{y}(q). \tag{5}$$

Note that, in view of (3), $R(q)$ denotes total tax as well as average tax revenues. The tax and refund rates are related through the government's budget constraint[8]

$$R(q) = (q-1)\overline{y}(q) = g_r\overline{r} + g_w\overline{w}. \tag{6}$$

Using (4), one can also write the government's budget constraint in another useful way,

$$\overline{I} = \int_0^1 I(\theta)f(\theta)d\theta = \overline{m} + R(q). \tag{7}$$

Observe that, in light of (6), the government has only two degrees of freedom in choosing its policy instruments. To represent the refund system through a single parameter, we introduce the concept of a "refund rule". The rule specifies the proportion of tax proceeds that must be refunded

[7]Our rationale for disallowing this type of tax is thus the same as in a Ramsey world. It is adopted not because it is deemed "realistic". Instead, it is intended to capture other complexities that the simple structure of a model such as ours leaves out. For example, if the externality affects different people differently (i.e. $\varphi(Y)$ in (1) depends on one's type), uniform lump-sum refunds will no longer be in general sufficient to achieve a first-best outcome.

[8]Alternatively, we can explicitly introduce the existing taxes on capital and wage income. Then the government's budget constraint is given by

$$\widehat{t}_r\overline{r} + \widehat{t}_w\overline{w} = \overline{R},$$

where $\hat{t}_r$ and $\hat{t}_w$ are the tax rates while $\overline{R}$ is the revenue requirement. Introducing environmental taxation and giving rebates, we will have

$$(q-1)y(q) + (\hat{t}_r - g_r)\overline{r} + (\hat{t}_w - g_w)\overline{w} = \overline{R},$$

which is equivalent to (6).

on the basis of wage incomes. This proportion, denoted by α, is defined formally as

$$\alpha = \frac{g_w \overline{w}}{R(q)} \tag{8}$$

with $0 \leq \alpha \leq 1$ due to the restriction on the signs of g_r and g_w. The tax-cum-refund policy is then completely characterized by the two parameters q and α.

Finally, define

$$\delta(\theta, \alpha) \equiv (1-\alpha)\frac{r(\theta)}{\overline{r}} + \alpha\frac{w(\theta)}{\overline{w}}. \tag{9}$$

It will become clear below that δ is a crucial ingredient for determining an individual's tax preferences. It shows the proportion of tax revenues that a person of type θ gets back in refunds.[9] Observe that $\delta(\theta, \alpha)$ is an increasing function of θ ($\delta_\theta(\theta, \alpha) > 0$), and a linear function of α with the slope

$$\delta_\alpha(\theta) = \frac{w(\theta)}{\overline{w}} - \frac{r(\theta)}{\overline{r}}. \tag{10}$$

2.2 Optimal tax benchmark

This subsection studies the nature of optimal environmental tax in our setting which rules out uniform lump-sum refunds. To obtain the utilitarian optimum, write the sum of utilities as

$$W^F = \int_0^1 v(q, I(\theta), Y) f(\theta) d\theta = a(q) + b(q)\overline{I} - \varphi(Y).$$

The government maximizes W^F subject to its budget constraint. Incorporating the government's budget constraint (7) in W^F, we obtain

$$W^F = a(q) + b(q)[\overline{m} + R(q)] - \varphi(\overline{y}(q)). \tag{11}$$

Observe that this expression is independent of α; that is, the value of α has no bearing on social welfare. This is because, with Gorman-polar form

[9] To see this, substitute for α from (8) into (9). This yields

$$\delta(\theta, \alpha) = \frac{g_r r(\theta) + g_w w(\theta)}{R(q)}.$$

preferences, and a utilitarian social welfare function, redistributive considerations do not matter (with a utilitarian objective): all individuals have a constant marginal utility of income equal to $b(q)$. Maximizing W^F with respect to q, assuming an interior optimum, yields

$$(q^F - 1) = \frac{\varphi'(Y^F)}{b(q^F)}, \tag{12}$$

where $Y^F = \overline{y}(q^F)$.[10] This is the standard Pigouvian tax rule so that q^F denotes the *first-best* value of q. In words, the per unit tax on the polluting good, $(q^F - 1)$, equals the marginal social damage of the externality.[11]

3 The pollution tax under majority voting

Throughout the paper, we shall assume that the pollution tax is determined through a majority voting process. The vote takes place conditional on the refund rule, namely, for a given value of α. The value of α is set by a welfare-maximizing public authority. The authority, when setting α, anticipates its influence on the majority equilibrium value of the tax. This section studies the determination of $q^E(\alpha)$, a function specifying the majority voting equilibrium induced by a given value of α. The choice of α will be discussed in the following section.

[10] The second-order condition is

$$\left[1 - \frac{\varphi''(Y^F)\overline{y}'(q^F)}{b(q^F)} + \frac{\varphi'(Y^F)}{b'(q^F)^2}\right] b(q^F)\overline{y}'(q^F) < 0.$$

This is satisfied in light of $\varphi'(.) > 0, \varphi''(.) \geq 0$ and $\overline{y}'(.) < 0$. Note also that, with $\varphi(.)$ and $\overline{y}(.)$ monotonic, and twice continuously differentiable,

$$\frac{\partial W^F}{\partial q} = b(q)\left[(q-1) - \frac{\varphi'(\overline{y}(q))}{b(q)}\right]\overline{y}'(q)$$

has a unique solution at q^F, is always positive to the left of q^F and negative to its right. This implies that W^F is increasing everywhere to the left of q^F and decreasing to its right, with q^F yielding the global maximum.

[11] This rule holds for any social welfare function, utilitarian or otherwise, as long as the solution is first best. That it applies here, despite the absence of a uniform lump-sum tax instrument, reflects the fact that with a utilitarian objective and Gorman-polar form preferences, redistributional concerns do not matter. The optimal tax will not be characterized by (12) if either of these two assumptions do not hold.

3.1 The majority voting equilibrium

Assume that α is given with $0 \leq \alpha \leq 1$. We first tackle the problem of the existence of a majority voting level of q for any given value of α. To do so we use (1), (3), (4) and (8), to express the utility of individual θ, as a function of α, q *and* g_r

$$U(q,\alpha,g_r,\theta) = a(q)+\left[(1+g_r)\,r(\theta)+\left(1+\frac{\alpha}{1-\alpha}g_r\frac{\overline{r}}{\overline{w}}\right)w(\theta)\right]b(q)-\varphi(y(q)). \tag{13}$$

Note that (13) does not make use of (6), i.e. of the government's budget constraint. Denote the income elasticity of demand for y by $\varepsilon_I = (\partial y/\partial I)(I/y)$ and assume that ε_I satisfies the following property:

Assumption 2 *We have*

$$\varepsilon_I < \frac{\delta_\theta}{\delta}\frac{I}{I_\theta}\left(1+\frac{\varphi'(\overline{y})\overline{y}'}{b(q)y}\right) = \left(\frac{\frac{\theta\delta_\theta}{\delta}}{\frac{\theta I_\theta}{I}}\right)\left(1+\frac{\varphi'(\overline{y})\overline{y}'}{b(q)y}\right), \tag{14}$$

for any $\theta \in [0,1]$, $\alpha \in [0,1]$ *and* $q > 1$.

The right-hand side of (14) is always positive and can take values greater as well as smaller than one. It is necessarily larger than one when the elasticity (with respect to θ) of δ is larger than that of I, i.e. when refund shares increase faster than disposable income. The assumption thus requires that the income elasticity of y is not "too large". It is always satisfied in a quasi-linear setting but it may be violated for homothetic preferences.[12] The intuition behind this assumption will become clear below; see the discussion of Lemma 2. In the Appendix we show that under Assumption 2, utility function (13) satisfies Gans and Smart's (1996) sufficient condition for the median individual to be decisive (in the vote over q, for any given value of α). This condition relies on the Spence-Mirrlees "single-crossing" property.

[12]With quasi-linear preferences, $\varepsilon_I = 0$ and the assumption is automatically satisfied regardless of the value of α. With homothetic preferences, $\varepsilon_I = 1$; on the other hand, the right-hand side of (14) is less than one whenever $\alpha > \overline{w}/\overline{m}$.

Applied to our setting, it requires that the marginal rates of substitution in the space (q, g_r) be monotonic in voters' type θ. Formally, the condition states that

$$MRS = -\frac{\partial U(q, \alpha, g_r, \theta)/\partial g_r}{\partial U(q, \alpha, g_r, \theta)/\partial q} \tag{15}$$

increases in θ. Denote the voting equilibrium by $q^E(\alpha)$ and the most preferred level of q of an individual $\theta \in [0, 1]$ by $q^*(\theta; \alpha)$, the proof in the Appendix establishes the following lemma.

Lemma 1 *Under Assumption 2 , there exists a majority-voting equilibrium level of q for any $\alpha \in [0, 1]$; it is given by the most preferred choice of the median individual. We have*

$$q^E(\alpha) = q^*(\widehat{\theta}; \alpha), \qquad \forall \alpha \in [0, 1].$$

To determine the properties of the voting equilibrium $q^E(\alpha) = q^*(\widehat{\theta}; \alpha)$, we first examine the properties of $q^*(\theta; \alpha)$; i.e., the most-preferred value of q for an individual of type θ.

3.2 Tax preferences of a θ-type person

Incorporate the government's budget constraint (6) in the θ-type individual's budget constraint (4). Using the definition of α in (8), and $\delta(\theta, \alpha)$ in (9), we have

$$I(\theta, q) = m(\theta) + \delta(\theta, \alpha)R(q). \tag{16}$$

Next, substitute (16) into the individual's indirect utility function (1) to obtain the reduced indirect utility function,

$$V(q, \alpha, \theta) = a(q) + b(q)\big[m(\theta) + \delta(\theta, \alpha)R(q)\big] - \varphi(\overline{y}(q)). \tag{17}$$

It is clear from (17) that the size of $\delta(\theta, \alpha)$ is a crucial determinant of the impact of q on $V(q, \alpha, \theta)$. Moreover, $\delta(\theta, \alpha)$ is the only *direct* channel through which α affects $V(q, \alpha, \theta)$.

Partially differentiate (17) with respect to q and simplify, making use of Roy's identity. We have

$$\frac{\partial V(q,\alpha,\theta)}{\partial q} = -b(q)y(q,\theta) + b(q)\delta(\theta,\alpha)R'(q) - \varphi'(\overline{y}(q))\overline{y}'(q).$$

The first expression in the right-hand side shows the direct change in utility as a result of changing the tax rate and thus q. This is of course a loss. The second term shows the direct gain through refunds. The third expression shows the indirect gain through the reduction of emission damage as aggregate consumption of y decreases. The optimal tax balances all these trade offs.

It will be useful to rewrite the above equation as

$$\begin{aligned} \frac{\partial V(q,\alpha,\theta)}{\partial q} &= b(q)\Big\{\overline{y}(q) - y(q,\theta) + \big[\delta(\theta,\alpha) - 1\big]R'(q) \\ &- \big[\frac{\varphi'(\overline{y}(q))}{b(q)} - (q-1)\big]\overline{y}'(q)\Big\}. \end{aligned} \quad (18)$$

Now assume $V(q,\alpha,\theta)$ has an interior maximum in

$$q^*(\theta;\alpha) = \arg\max_q [V(q,\alpha,\theta)],$$

so that

$$\frac{\partial V(q^*(\theta;\alpha),\alpha,\theta)}{\partial q} \equiv 0, \quad (19a)$$

$$\frac{\partial^2 V(q^*(\theta;\alpha),\alpha,\theta)}{\partial q^2} < 0, \quad (19b)$$

and that $q^*(\theta;\alpha)$ is continuous in θ and α. Finally, evaluating (18) at $q^*(\theta;\alpha)$ yields

$$\overline{y}(q^*) - y(q^*,\theta) + \big[\delta(\theta,\alpha) - 1\big]R'(q^*) = -\overline{y}'(q^*)\big[(q^*-1) - \frac{\varphi'(\overline{y}(q^*))}{b(q^*)}\big].$$

It follows from the above equation that

$$\big[\delta(\theta,\alpha) - 1\big]R'(q^*) \gtreqqless y(q^*,\theta) - \overline{y}(q^*) \;\;\Leftrightarrow\;\; q^* - 1 \gtreqqless \frac{\varphi'(\overline{y}(q^*))}{b(q^*)}. \quad (20)$$

Recall from (9) that $\delta(\theta,\alpha)$ shows the proportion of one's refunds to average refunds. Then $\big[\delta(\theta,\alpha) - 1\big]R'(q^*)$ shows the rate at which a θ-type person benefits, *relative to the "average person,"* from a marginal increase in the tax through his refund. Similarly $y(q^*, \theta) - \overline{y}(q^*)$ shows the θ-type's rate of loss, again *relative to the average person,* from a marginal increase in the tax, due to his "extra" (above average) consumption of the polluting good. Equation (20) then tells us that whether an individual of type θ prefers a tax larger, equal to, or smaller than the marginal social damage of emissions depends on whether his extra gain is larger, equal to, or smaller than his extra loss.

Condition (20) describes the relationship between a person's desired tax rate and the resulting marginal social damage of emissions at that tax rate. To translate this into a relationship between the desired tax and the first-best Pigouvian tax, recall that q^F is the solution to $q - 1 = \varphi'(\overline{y}(q)/b(q)$. Moreover, we show in the Appendix that $q - 1 - \varphi'(\overline{y}(q))/b(q)$ is monotonically increasing in q,[13] so that

$$q^* - 1 \gtreqless \frac{\varphi'(y(q^*))}{b((q^*)} \quad \Leftrightarrow \quad q^* \gtreqless q^F. \tag{21}$$

The next interesting question concerns the relationship between individuals' types and their desired tax rates. Define $\overline{\theta}(\alpha)$ as the solution to $\left[\delta(\theta, \alpha) - 1\right] R'(q^*) = y(q^*, \theta) - \overline{y}(q^*)$, so that $q^*(\overline{\theta}(\alpha); \alpha) \equiv q^F$. We have

Lemma 2 *Under Assumption 2, $q^*(\theta; \alpha)$ is a strictly increasing function of θ so that all individuals with $\theta > \overline{\theta}(\alpha)$ would prefer a higher-than Pigouvian tax, and all individuals with $\theta < \overline{\theta}(\alpha)$ would prefer a lower-than Pigouvian tax.*

The Proof of Lemma 2 is given in the Appendix. To understand the intuition behind it, and the role played by Assumption 2, recall that an individual's tax preferences are affected by his type θ, and thus his income, in two ways. First, because $\delta_\theta > 0$, an individual with a higher income will receive a higher share of the refunded tax revenue. As a result, he will tend

[13] This is the case for the energy-related polluting goods we are considering here.

to favor a higher tax rate. However, when ε_I is positive, a higher income individual will consume more of the polluting good and thus pay more taxes. According to this second effect, then, high income individuals tend to prefer lower tax rates. Now, if the income elasticity is not too large, the first effect dominates and we have the result stated in Lemma 2.

3.3 Properties of the majority-voting equilibrium

Prior to investigating the properties of the majority voting equilibrium for *any* value of α, consider the special case where α is such that $g_r = g_w = g$. In this case, tax refunds are proportional to *total* income m. Using (8), one can easily verify that this requires

$$\alpha = \underline{\alpha} \equiv \frac{\overline{w}}{\overline{w} + \overline{r}}. \tag{22}$$

Evaluating $\delta(\theta, \alpha)$ at $\underline{\alpha}$ yields .

$$\delta(\theta, \underline{\alpha}) = \frac{m(\theta)}{\overline{m}}. \tag{23}$$

It follows from (23) that in this case a person with the mean income will have $\delta(\theta, \underline{\alpha}) = 1$. He will also have an after-tax income equal to $\overline{I}$ [see equations (7) and (16)], and consume $y(q^*, \theta) = \overline{y}(q^*)$. Consequently, for $\underline{\alpha}$, the person with mean income is the "average" person who desires the Pigouvian tax. We thus have $\widehat{\theta} < \overline{\theta}(\underline{\alpha})$. Given that the individual $\overline{\theta}$ prefers the Pigouvian tax level, we have established the following proposition.

Proposition 1 *Under Assumption 2, when refunds are proportional to total income majority voting results in a pollution tax which is smaller than the Pigouvian tax; that is,* $q^E(\underline{\alpha}) < q^F$.

We now return to the voting problem for an arbitrary level of α and begin by making a further assumption on ε_I.

Assumption 3 *We have, for all* $0 \leq \alpha \leq 1$,

$$\varepsilon_I(q^E, \widehat{\theta}) < \frac{I(q^E, \widehat{\theta})}{y(q^E, \widehat{\theta})} \frac{R'(q^E)}{R(q^E)} = \left(\frac{I(q^E, \widehat{\theta})}{q y(q^E, \widehat{\theta})} \right) \left(\frac{q R'(q^E)}{R(q^E)} \right). \tag{24}$$

This assumption also stipulates that the income elasticity of demand for y is not too large. Observe that the RHS of this expression is greater than one if the revenue elasticity $qR'(q^E)/R(q^E)$ exceeds the budget share for y. Consequently, it holds for sufficiently low expenditure shares, given the revenue elasticity. Observe also that this condition is automatically satisfied for quasi-linear preferences as in that case $\varepsilon_I = 0$. With homothetic preferences, $\varepsilon_I = 1$, and to have this condition satisfied, $R'(q^E)/R(q^E)$ must be greater than $y(q^E, \widehat{\theta})/I(q^E, \widehat{\theta})$.

It is clear from Lemma 2 that whether the median voter desires a tax rate smaller or greater than the Pigouvian tax depends on whether he is to the left or to the right of $\overline{\theta}(\alpha)$. The following proposition shows that α and q^E move positively together. This establishes a link between $\widehat{\theta}$ and $\overline{\theta}(\alpha)$ which will prove useful later on.

Proposition 2 *Under Assumption 3, $q^E(\alpha)$ is increasing in α.*

The proposition is proved in the Appendix. The intuition for it comes from equations (10), (17), and (18). With $\widehat{w}/\overline{w} > \widehat{r}/\overline{r}$, $\delta_\alpha(\widehat{\theta}) > 0$, so that an increase in α increases the share of the tax revenue which is reimbursed to the median voter. Assumption 3 then ensures that his expenditures on y, and thus his tax payments, do not go up that much as to more than offset the benefits of extra refunds.

An interesting implication of Propositions 1 and 2 is that $q^E(\alpha) < q^F$ for all $\alpha \leq \underline{\alpha}$. In other words, a low level of α guarantees inefficiency. The case where $\alpha > \underline{\alpha}$ will be considered in the next section which studies the determination of α by a welfare maximizing authority who is constrained by the political process, i.e., by the second-stage voting game on q.

4 The "optimal" level of α

With a utilitarian social welfare function, welfare, when q corresponds to the voting equilibrium $q^E(\alpha)$, is given by

$$W^U(\alpha) = \int_0^1 V(q^E(\alpha), \alpha, \theta) f(\theta) d\theta. \tag{25}$$

Note that V is given by (17) so that it incorporates the budget constraints of the government and the individuals, as well as the value of Y. Substituting from (17), using (9) and rearranging, we obtain

$$W^U(\alpha) = a\left(q^E(\alpha)\right) + b(q^E(\alpha))\left[\overline{m} + R(q^E(\alpha))\right] - \varphi\left(\overline{y}(q^E(\alpha))\right). \tag{26}$$

The expression for W^U is identical to the one for W^F except that $q^E(\alpha)$ replaces q. This expression shows that α has no *direct* impact on welfare; it affects W^U only indirectly, through its effect on q. Put differently, the sole role played by α is that it can bring about a "suitable" voting equilibrium in the second stage. This property arises because redistribution does not matter here; see section 2.2.

It is now a simple exercise to determine α^U, the optimal value of α. To maximize (26), one sets α to ensure that $q^E(\alpha)$ is as close as possible to q^F.[14] We know from Proposition 1 that at $\alpha = \underline{\alpha}$, $q^E < q^F$. It follows from Proposition 2 that we have to increase α from $\underline{\alpha}$. The crucial question is whether there exists an $\alpha < 1$ at which $q^E = q^F$. If yes, then that is the optimal choice for α; otherwise α must be raised all the way up to one. In turn, the answer to the existence of an interior solution for α lies in Condition (20). Specifically, the question is whether there exists an $\alpha < 1$ at which $\delta(\widehat{\theta}, \alpha)$ reaches

$$\frac{\widehat{y}(q^F) + (q^F - 1)\overline{y}'(q^F)}{\overline{y}(q^F) + (q^F - 1)\overline{y}'(q^F)},$$

or always remains below it.

[14] This follows from the properties of W^F: q^F maximizes W^F with W^F increasing everywhere to the left of q^F and decreasing to its right.

With $\delta_\alpha > 0$, δ attains its highest value at $\alpha = 1$ so that $\delta(\widehat{\theta}, 1) = \widehat{w}/\overline{w}$. There will then be no interior solution for α if

$$\frac{\widehat{w}}{\overline{w}} < \frac{\widehat{y}(q^F) + (q^F - 1)\overline{y}'(q^F)}{\overline{y}(q^F) + (q^F - 1)\overline{y}'(q^F)}. \tag{27}$$

Simplifying condition (27) while making use of (2), we have[15]

Proposition 3 *Under Assumption 3:*

(i) If

$$d(q^F) < \frac{\left[c(q^F) + (q^F - 1)\overline{y}'(q^F)\right](\overline{w} - \widehat{w})}{\widehat{w}\overline{r} - \overline{w}\widehat{r}}, \tag{28}$$

it is optimal to base refunds entirely on labor income ($\alpha^U = 1$). This induces a majority voting pollution tax which remains below the Pigouvian level: $q^U = q^E(\alpha^U) < q^F$.

(ii) Otherwise, $\alpha^U \leq 1$ is the solution to

$$\delta(\widehat{\theta}, \alpha) = \frac{\widehat{y}(q^F) + (q^F - 1)\overline{y}'(q^F)}{\overline{y}(q^F) + (q^F - 1)\overline{y}'(q^F)}, \tag{29}$$

and $q^U = q^E(\alpha^U) = q^F$.

Proposition 3 shows that a welfare maximizing government will always refund a higher proportion of wage incomes than of capital incomes (i.e. $g_w > g_r$), when rebating environmental tax revenues. This is because the tax refund formula is set to affect the outcome of the voting procedure in order to mitigate the negative bias of the median voter against the environmental tax. The negative bias will be completely eliminated, if there exists a sufficiently high value for α at which $q^U = q^E(\alpha^U) = q^F$. Otherwise, the negative bias will be eliminated only in part. The tax rate will be higher than under a uniform reimbursement scheme (with $g_r = g_w$), but it falls short of the Pigouvian solution. That outcome will be politically infeasible.

[15] Recall that $y(q;\theta) = c(q) + d(q)I(\theta)$ where $c(q) = -a'(q)/b(q) > 0$, and $d(q) = -b'(q)/b(q) > 0$. To arrive at (28), use the equation for $y(q;\theta)$ to substitute for $\widehat{y}$ and $\overline{y}$ in (27). This yields

$$d(q^F)(\overline{I}\widehat{w} - \widehat{I}\overline{w}) < (\overline{w} - \widehat{w})\left[c(q^F) + (q^F - 1)\overline{y}'(q^F)\right].$$

Next, substitute $\overline{I} = \overline{w} + \overline{r}$ and $\widehat{I} = \widehat{w} + \widehat{r}$ in above, simplify and rearrange.

Observe also that whether Condition (28) is satisfied or not depends on the individuals' preferences for y as well as wage and capital income distributions. If preferences are quasi-linear, for example, $d(q) = 0$, and the condition is *never* violated (given the assumption that $\widehat{r}/\overline{r} < \widehat{w}/\overline{w} < 1$.) On the other hand, when $d(q) > 0$, the "likelihood" that Condition (28) is violated would be greater the smaller is $(\overline{w} - \widehat{w})/(\widehat{w}\overline{r} - \overline{w}\widehat{r})$. That is, the closer is $\widehat{w}$ to $\overline{w}$ and the farther is $\widehat{r}/\overline{r}$ away from $\widehat{w}/\overline{w}$.

In concluding this section, we note that our results evoke an interesting parallelism with the so-called "double dividend hypothesis"; see e.g. Goulder (1995). Proposition 3 tells us that we will always have $g_w > g_r$ with the possibility that $\alpha^U = 1$. That is to say environmental taxes must be refunded proportionately more through a reduction in wage taxes than in capital income taxes. The double dividend hypothesis claims that the recycling of tax revenues, in particular through reductions in taxes on labor income, is a crucial ingredient of environmental tax policy. Our results suggest that the significance of this aspect is not necessarily linked to the reduction of distortions associated with the pre-existing taxes, as customarily claimed. Instead, this plays an important role in ensuring political support for a policy which would otherwise be politically infeasible. Specifically, it is the political support argument that calls for a refund through reductions in labor taxes.

5 Summary and conclusion

How big an environmental tax does the society support? This paper has argued that the answer to this question is crucially influenced by whose income taxes are reduced in order to keep the government's budget balanced. In studying this issue, we assumed that the society acts on these questions sequentially. It decides first on the government's refund rule that determines who pays what income taxes, and then on the level of the environmental tax. The tax level is decided through a majority voting process. The refund rule is set at a constitutional stage by a welfare maximizing authority (who anticipates the induced voting equilibrium of the second stage).

We showed that if labor and capital income taxes are reduced in the same proportion, majority voting entails a bias against environmental taxes (assuming the median income is smaller than mean income). That is, it yields a rate of environmental taxation that is lower than the optimal (Pigouvian) level. We also showed that the equilibrium tax rate is increasing in the proportion of tax reductions based on wage incomes.

We proved that the constitutional planner will always reduce the tax on the labor income proportionally more than the tax on the capital income. In this way, the planner mitigates the negative bias of the median voter against environmental taxes. The planner may even be able to achieve the first-best outcome depending on the individuals' preferences for the polluting good, and the distributions of wage and capital incomes. If the first-best Pigouvian tax is not feasible (as it will be the case if preferences are quasi-linear), the planner will base all the refunds on wage incomes. This will result in an equilibrium tax rate higher than that under a uniform tax reduction scheme, but it falls short of the Pigouvian solution.

This particular result explains why the supporters of environmental taxes play up the recycling of tax revenues, particularly through reductions in wage income taxes, as a crucial ingredient of environmental tax policy. While the recycling argument is usually framed in terms of reducing other distortionary taxes in the economy, we argued that the real reason may lie elsewhere. Wage income tax reductions ensure support for a policy (i.e. a tax level) which would otherwise be politically infeasible.

Appendix

Proof of Lemma 1: Individual θ's marginal rate of substitution between g_r and q, for any value of α, is given by

$$\begin{aligned} MRS(q, g_r; \alpha, \theta) &= -\frac{\partial U(q, \alpha, g_r, \theta)/\partial g_r}{\partial U(q, \alpha, g_r, \theta)/\partial q} = \frac{r(\theta) + \frac{\alpha}{1-\alpha}\frac{\overline{r}}{\overline{w}} w(\theta)}{b(q)y(q;\theta) + \varphi'(\bar{y}(q))\bar{y}'(q)} \\ &= \frac{\delta(\theta, \alpha)}{1-\alpha} \frac{\overline{r}}{b(q)y(q;\theta) + \varphi'(\bar{y}(q))\bar{y}'(q)}. \end{aligned}$$

Observe that $MRS(q, g_r; \alpha, \theta)$ is not in general monotone with θ because both the denominator and the numerator increase with θ. More precisely, we have

$$\begin{aligned} \frac{\partial MRS(q, g_r; \alpha, \theta)}{\partial \theta} &= \frac{\overline{r}}{1-\alpha} \Big\{ \frac{\delta_\theta(\theta, \alpha)}{b(q)y(q;\theta) + \varphi'(\bar{y}(q))\bar{y}'(q)} \\ &- \frac{\delta(\theta, \alpha) b(q) y_\theta(q;\theta)}{\left[b(q)y(q;\theta) + \varphi'(\bar{y}(q))\bar{y}'(q)\right]^2} \Big\}. \end{aligned}$$

For the single-crossing condition to hold, the sign of this derivative must be the same for all values of the parameters q, g_r, α and θ. Now, with the quasi-linear utility, which is a special case of the Gorman-polar utility used here, $y_\theta = 0$. This implies that the above expression will be positive. Consequently, the required condition for the class of Gorman-polar utility functions is that the sign of the above derivative must be positive.

Imposing the condition that

$$\frac{\partial MRS(q, g_r; \alpha, \theta)}{\partial \theta} > 0$$

is then equivalent to

$$\delta_\theta(\theta, \alpha)\left[b(q)y(q;\theta) + \varphi'(\bar{y}(q))\bar{y}'(q)\right] > \delta(\theta, \alpha) b(q) y_\theta(q;\theta),$$

or,

$$\varepsilon_I < \frac{\delta_\theta}{\delta} \frac{I}{I_\theta} \left(1 + \frac{\varphi'(\overline{y})\overline{y}'}{b(q)y}\right).$$

Under this condition, the median individual is decisive when voting on (q, g_r) which, given the degree of freedom lost when incorporating (6), amounts to a vote on q.

Validity of the claim that $f(q) \equiv q - 1 - \varphi'(\overline{y}(q))/b(q)$ **is monotonically increasing in** q : Differentiating $f(q)$ and simplifying, we have

$$f'(q) = 1 - \frac{\varphi''(Y)\overline{y}'(q) + d(q)\varphi'(Y)}{b(q)}. \tag{A1}$$

It follows from (A1) that $f'(q)$ will always be positive if

$$d(q) < \big[1 - \frac{\varphi''(Y)\overline{y}'(q)}{b(q)}\big]\frac{b(q)}{\varphi'(Y)}. \tag{A2}$$

Now, with $c(q) > 0$, we have

$$d(q) < \frac{y(q)}{I} \leq \frac{qy(q)}{I} < 1.$$

Moreover, observe that the first bracketed expression in the right-hand side of (A2) is greater than one. It thus follows that a sufficient condition for the inequality in (A2) to be satisfied is that if

$$\frac{b(q)}{\varphi'(Y)} > 1. \tag{A3}$$

This inequality tells us that we require the marginal social damage of emissions from a unit of polluting good to be less than the unit cost of producing the polluting good. Cremer *et al.* (2003) have calculated, on the basis of the published values for the social damage of carbon emissions (which is the relevant damage here given our conception of y), the *maximum value*, that the marginal social damage of emissions relative to the cost of production of one unit of energy-related goods is about 4%. This is far less than the 100% ratio required for our sufficient condition to be satisfied.

Proof of Lemma 2: Observe that $q^*(\theta;\alpha)$ is obtained by maximizing $U(q, \alpha, g_r(q), \theta)$ with respect to q [where $g_r(q) = (1-\alpha)R(q)/\overline{r}$ is independent of θ]. The first-order condition is given by

$$U_q + U_g \frac{dg_r}{dq} = 0. \tag{A4}$$

Condition (A4) must hold for all values of θ. Differentiating it with respect to θ, we obtain

$$\left(U_{q\theta} + U_{g\theta}\frac{dg_r}{dq}\right) d\theta + D dq = 0, \tag{A5}$$

where

$$D \equiv \frac{\partial (U_q + U_g \frac{dg_r}{dq})}{\partial q} < 0.$$

The sign of D follows from the second-order condition of the maximization of $U(q, \alpha, g_r(q), \theta)$ with respect to q. It then follows from (A5) and (A4) that

$$\frac{\partial q^*(\theta;\alpha)}{\partial \theta} = -\frac{U_{q\theta} + U_{g\theta}\frac{dg_r}{dq}}{D} = -\frac{U_{q\theta} - U_{g\theta}\frac{U_q}{U_g}}{D}.$$

Consequently, with $U_g > 0$,

$$\frac{\partial q^*(\theta;\alpha)}{\partial \theta} > 0 \qquad \Leftrightarrow \qquad U_{q\theta}U_g - U_{g\theta}U_q > 0.$$

To complete the proof, differentiate the expression for the MRS between g_r and q in (15) with respect to θ. We have

$$\frac{\partial MRS}{\partial \theta} = -\frac{U_q U_{g\theta} - U_g U_{q\theta}}{U_q^2}.$$

Now, under Assumption 2, this MRS is increasing in θ so that

$$U_g U_{q\theta} - U_q U_{g\theta} > 0. \tag{A6}$$

Proof of Proposition 2: Observe that $dq^E(\alpha)/d\alpha$ has the same sign as $\partial^2 V(q^E, \alpha, \widehat{\theta})\ /\partial\alpha\partial q$. This follows from differentiating $\partial V(q^*(\theta;\alpha), \alpha, \theta)/\partial q$ in (19a) totally with respect to α and the sign of $\partial^2 V(q^*(\theta;\alpha), \alpha, \theta)/\partial q^2$ in (19b) evaluated at $\theta = \widehat{\theta}$. Now differentiating equation (18) partially with respect to α yields

$$\begin{aligned} \frac{\partial^2 V(q,\alpha,\theta)}{\partial\alpha\partial q} &= b(q)\big[R'(q) - d(q)R(q)\big]\delta_\alpha(\theta) \\ &= b(q)\big[R'(q) - d(q)R(q)\big]\big[\frac{w(\theta)}{\overline{w}} - \frac{r(\theta)}{\overline{r}}\big]. \end{aligned}$$

Evaluated at $\widehat{\theta}$ and $q^*(\widehat{\theta};\alpha)$, this tells us that a sufficient condition for $dq^E(\alpha)/d\alpha > 0$ is

$$d(q^E) < \frac{R'(q^E)}{R(q^E)} = \varepsilon_R(q^E)\frac{1}{q^E - 1} = \varepsilon_R(q^E)\frac{\widehat{y}(q^E)}{R(q^E)} = \varepsilon_R(q^E)\frac{\widehat{y}(q^E)}{\widehat{I}(q^E) - \widehat{m}}, \tag{A7}$$

which is equivalent to Assumption 3.

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