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## The Political Sustainability of Germany's Environmental Tax Rate

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# Intergenerational Aspects of Ecotax Reforms - an Application to Germany\*

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**Abstract:** In a model of overlapping generations and majority voting, we analyze an ecotax reform consisting of the tax rate and the budgetary rule. Revenue can be recycled either through a lump-sum transfer or a reduction in pension contributions. Our theoretical results as well as the calibration of our model to the German economy show that the median voter's preferred tax rate may lie close to or even exceed the efficient tax rate. This holds whenever income of the decisive voter is sufficiently high as high-income individuals benefit more from a reduction in pension contributions than they are harmed by an increase in ecotaxes. The calibration confirms that the median voter prefers earmarking of tax revenue as reductions in pension contributions to the alternative lump-sum transfer. This is quite an accurate prediction of the situation in Germany where the share of tax revenue devoted to the pension scheme amounts to more than 90%. Aging of society as expected for Germany threatens to lower the ecotax rate in the political equilibrium below its optimal level.

**Keywords:** Majority Voting, Environmental Taxes, Pigouvian Taxes, OLG

**JEL-Classification:** H21 · H23 · Q58

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# 1 Introduction

As part of the growing awareness of fighting environmental problems such as climate change, ecotax reforms have been carried out in many European countries over the course of the last two decades. Beside the environmental benefit of internalizing the externality caused by greenhouse gas emissions, environmental taxes may reap a second ‘dividend’: the revenue generated by ecotaxes can be recycled as cuts in distortionary taxes such as taxes on labor, entailing welfare gains for the whole economy. This idea has given rise to the so-called ‘double dividend’ hypothesis (see Bovenberg, 1999, or Bovenberg and Goulder, 2002, for excellent surveys).

Despite the scientific controversy whether the double dividend is realized or not, Germany introduced an ecotax in five yearly steps between 1999 and 2003. It is levied on mineral oil consumed by households and firms which are not part of the manufacturing industry and also covers non-renewable energy inputs. A revenue of approximately €18 billion is raised annually, 90% of which are recycled as reductions in pension contributions.<sup>1</sup> Without this part of the ecotax revenue, pension contributions would have to rise by 1.7 percentage points in order to keep pension benefits at their current levels (see Bach, 2009). The ecotax reform turned into a prominent campaign issue for the German parliamentary elections particularly in 1998 and 2002. Since then the slogan ‘Tanken für die Rente’ (refuel for old-age pensions) has become a well-known saying in the German public.<sup>2</sup>

In this paper, we ask how, *under majority voting*, ecotax reforms interact with institutional settings which are already in place and – at least in the short run – unchangeable. Linking ecotaxes to existing systems might alter the political equilibrium as voter coalitions are affected differently by the proposed reform. We take the German policy as a starting point where it is the size of the pension system which is not open to debate, and where it is the contributors as compared to the retirees who benefit from the recycling of ecotax revenue. In a similar manner, countries such as the UK, Sweden or Denmark have adopted ecotax reforms which take pressure from social security systems and the general public budget by cutting social security or personal income taxes (see Bosquet, 2000, for details). We will argue that these ecotax reforms have similar effects when it comes to their political acceptability among voters.

Although it is very difficult to put a precise number on marginal damages from carbon

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<sup>1</sup>The remainder is used for other purposes such as subsidies on renewable energy.

<sup>2</sup>See, *e.g.*, an article on Deutschlandradio in 2004: <http://www.dradio.de/dlf/sendungen/hiwi/251994/>

dioxide emissions and hence on the socially optimal tax rate (estimates from the IPCC's Second Assessment Report in 1995 alone range from \$5 to \$150 per tonne of carbon), our model allows for an implicit comparison of the socially optimal and the politically induced tax rate. While the price of under €10 per tonne of carbon dioxide ( $CO_2$ ) in the European Union's emissions trading scheme<sup>3</sup> as of April 2012 is generally considered too low, the German ecotax on gasoline, for example, is equivalent to a carbon price of €65 per tonne of  $CO_2$ .<sup>4</sup> The relatively high price of  $CO_2$  implied by the German ecotax can be explained by analyzing the incentives different generations face under the proposed ecotax package. The package consists of the green tax rate and the budgetary rule according to which a fraction of tax revenue is used to finance reductions in pension contributions. The remainder is distributed back in a lump-sum fashion as is standard in the environmental taxation literature.

Specifically, the model comprises two generations at each point in time – the young and the old. The young work and contribute to the pension scheme whereas the old are retired and enjoy pension benefits. Apart from age, agents differ in their income. They have preferences over two categories of consumer goods – ‘non-dirty’ and ‘dirty’ – and the total level of emissions in the atmosphere. A negative consumption externality arises from the consumption of dirty goods such as fossil fuels which cause emissions. All agents alive vote over the tax rate and the refunding rule in each period.

We resort to the notion of a ‘structure-induced equilibrium’ (Kramer, 1972; Shepsle, 1979) which separates the bi-dimensional policy space into single dimensions by assuming that institutions exist which have been assigned the unique power to determine policies related to their field of duties. In our model, the ministry of the environment proposes a green tax rate for a *given* share of revenue devoted to the pension scheme while the ministry of finance suggests a share of ecotax revenue devoted to the pension scheme for a *given* environmental tax rate. These proposals can be thought of as the best responses (reaction functions) of the ministries which are based on the median voter's preferences over the issue at stake. Their intersection characterizes the structure-induced equilibrium of the voting game. In other words, the structure-induced equilibrium introduces issue-by-issue voting and retains the median voter approach in a multi-dimensional issue space. We compare the political outcome with the ecotax package chosen by

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<sup>3</sup>Note that one tonne of carbon has to be multiplied with 44/12 to get  $CO_2$  emissions, see IPCC, 2006, p. 1.8.

<sup>4</sup>The ecotax for one liter of gasoline amounts to approximately €0.15, see website of the German treasury: [www.bundesfinanzministerium.de](http://www.bundesfinanzministerium.de). One liter entails  $CO_2$  emissions of approx. 2.3 kg, yielding a carbon price of €65 per tonne of  $CO_2$ .

a utilitarian social planner.

We find that the optimal ‘Pigouvian’ tax rate internalizes the full marginal damage from the polluting good for all current and future generations but also accounts for efficiency losses caused by the distortionary nature of pension contributions. What is more surprising is that majority voting yields a green tax rate which can be lower *or* higher than the optimal level. The intuition behind this result is as follows: although the social planner will always internalize more of the environmental damage out of environmental concerns compared to individuals, high-income earners benefit more from lowering pension contributions through higher ecotaxes than they are harmed by the tax increase through consumption. This is because young individuals contribute to the pension scheme proportionally to their incomes while the ecotax rate is regressive in nature. Therefore, if some share of tax revenue is devoted to the pension scheme, the median voter’s preferred environmental tax rate will be higher than the adjusted Pigouvian level whenever his income is sufficiently high. If, by contrast, all revenue is recycled via lump-sum transfers, the green tax rate in the political equilibrium is always below its efficient level.

The calibration of our model to the German economy illustrates that median voter income may indeed be high enough to raise the politically induced tax rate above its optimal level. The share of tax revenue devoted to the pension scheme is found to be unity. Furthermore, we find that a dramatic population aging as expected for Germany in the next few decades will lower the politically induced tax rate below its optimal level, starting from an inefficiently high or inefficiently low level.

Our paper contributes to two strands of literature. On the one hand, it adds to the literature on intergenerational aspects of environmental policy within an Overlapping Generations (OLG) framework (see, *e.g.*, Bovenberg and Heijdra, 1998 and 2002; Karp and Rezai, 2011; or Chiroleu-Assouline and Fodha, 2006). Intergenerational conflicts arise because of different distributional impacts of environmental taxes on the welfare of current generations. This is particularly true for the German ecotax package which is tied to the pension system. On the other hand, the paper contributes to the literature on the political economy of environmental taxation and the double dividend hypothesis. This strand of literature has been developed mainly by Cremer, De Donder, and Gahvari in a series of papers. In Cremer *et al.* (2004), the authors study how a welfare-maximizing government should set the refund rule at the constitutional stage when the ecotax rate is determined in the voting stage and when political competition arises within and between parties. In another paper, Cremer *et al.* (2007) examine the predictions of three political

economy models (the Downsian majority-voting approach, the probabilistic-voting model and Roemer (2006)'s model of Party Unanimity Nash Equilibria (PUNE)) for the determination of environmental taxes without a refunding rule and compare these predictions with an estimate of US energy taxes. The PUNE concept applied to environmental policy is explored in more detail in Cremer *et al.* (2008) where the budgetary rule constitutes a further policy instrument. Cremer, Gahvari and Ladoux (2010) study environmental taxation in a Mirrlees setting, with the polluting good being used both as a consumption good and input factor into production and with the wage rate being endogenously determined. Aidt (2010) studies the impact of industrial lobbying on a green tax package proposed by two competing parties which care about lobby contributions and voters. In his model, the proceeds from the ecotax can be recycled through income tax cuts, extra public spending or tax burden compensation to polluters. Our paper combines both strands of literature in the context of the German ecotax package, treating both the ecotax and the budgetary rule as endogenous. It is, to our knowledge, the first to consider intergenerational aspects of an ecotax package under majority voting.

The rest of the paper proceeds as follows. Section 2 introduces the economic environment and describes the economic equilibrium. Section 3 provides the normative benchmark against which the political outcome described in Section 4 is assessed. The implications of demographic change on our model are explored in Section 5 before the model is calibrated to the German economy in Section 6. The main results of the paper and some assumptions are discussed in Section 7. Section 8 concludes.

## 2 The Model

### 2.1 The Economic Environment

Consider an economy with two generations alive: the young (superscript ‘ $Y$ ’) and the old (superscript ‘ $O$ ’). Population grows at a constant rate  $n > 0$  and the size of the current old is normalized to one. It follows that in every period  $t$  for every young there are  $1/(1+n)$  old and the overall size of the population is given by  $2+n$ . The young go working, inelastically supply one unit of labor and earn income  $y_{i,t}$ . Income is distributed on the support  $[y^-, y^+] \subset \mathcal{R}_+$ , according to the cumulative distribution function  $F(y_t)$ . The distribution of income is assumed to have mean  $\bar{y}_t$  and to be right-skewed,  $F(\bar{y}_t) > 0.5$ , implying that median income is below average income. The old are retired and receive pension benefits. The pension scheme is pay-as-you-go

(PAYG), that is, the young pay a share  $b_t$  of their labor income into the pension scheme and the old get pension benefits  $B(y_{i,t-1})$  out of it. Note that, in this setup,  $1/(1+n)$  represents the pensioner/contributor ratio. In Germany, the pension scheme is (partly) Bismarckian, that is, pension benefits positively depend on the agent's prior income implying  $\partial B(y_{i,t-1})/\partial y_{i,t-1} > 0$ . There is no storage technology, so individuals do not save and solely live off their pension benefits in old age. The young and old derive utility from consumption of a non-polluting (non-energy) commodity  $c$  and from consumption of a polluting (energy-related) good  $d$ . The latter is taxed at a rate  $\theta_t \in \mathcal{R}$ . The price of the consumer good is normalized to one while the dirty good has a price of  $p_t$ . Aggregate consumption of the polluting good is:

$$D_t = (1+n) \int_{y^-}^{y^+} d_{i,t}^Y dF(y_t) + \int_{y^-}^{y^+} d_{i,t}^O dF(y_{t-1}). \quad (1)$$

One unit of the polluting good causes one unit of emissions. The stock of emissions in the atmosphere,  $E_t$ , brings about disutility  $h(E_t)$  where  $h' > 0$  and  $h'' = 0$ . One can think of the polluting good as fossil fuels whose consumption generates  $CO_2$  and contributes to global warming. The stock of emissions in period  $t$  is given by the stock in the previous period, reduced by the natural decay and removal rate  $\delta \in [0; 1]$  which we assume to be exogenous over time, and by the emissions from current consumption:

$$E_t = (1 - \delta)E_{t-1} + D_t. \quad (2)$$

Note that a decay rate equal to unity implies that pollution does not accumulate in the atmosphere.

The utilities of a young and old individual  $i$  read as follows:

$$U_{i,t}^Y = c_{i,t}^Y + u(d_{i,t}^Y) - h(E_t) + \rho U_{i,t+1}^O, \quad (3)$$

$$U_{i,t}^O = c_{i,t}^O + u(d_{i,t}^O) - h(E_t), \quad (4)$$

where  $\rho \leq 1$  is the utility discount factor and  $u$  is a utility function satisfying  $u' > 0$ ,  $u'' < 0$

and  $u''' > 0$ . The budget constraints of a young and an old agent read as follows:

$$c_{i,t}^Y + (p_t + \theta_t)d_{i,t}^Y = (1 - b_t)y_{i,t} + \tau_t, \quad (5)$$

$$c_{i,t}^O + (p_t + \theta_t)d_{i,t}^O = B(y_{i,t-1}) + \tau_t, \quad (6)$$

where  $\tau_t$  denotes a lump-sum transfer financed by taxation of the polluting good. Inserting (5) and (6) back into the utility functions of the young and old, equations (3) and (4), yields the following optimization problems for the two generations:

$$\max_{d_{i,t}^Y, d_{i,t+1}^O} U_{i,t}^Y = (1 - b_t)y_{i,t} + \tau_t - (p_t + \theta_t)d_{i,t}^Y + u(d_{i,t}^Y) - h(E_t) + \rho U_{i,t+1}^O. \quad (7)$$

$$\max_{d_{i,t}^O} U_{i,t}^O = B(y_{i,t-1}) + \tau_t - (p_t + \theta_t)d_{i,t}^O + u(d_{i,t}^O) - h(E_t), \quad (8)$$

Observe that variation in a single individual's consumption of the dirty good  $d_{i,t}$  does not have an impact on overall consumption  $D_t$  as the mass of one individual is close to zero. Assuming an interior solution, optimal consumption of the polluting good is thus implicitly given by:

$$p_t + \theta_t = u'(d_{i,t}^j) \Rightarrow d_{i,t}^j = d(\theta_t) \quad \forall i, t \quad \text{and for } j = Y, O. \quad (9)$$

As  $\partial d(\theta_t)/\partial \theta_t = 1/u'' < 0$ , consumption of the polluting good decreases with its tax rate. Additionally, it is independent of the individual's income and age. In other words, all individuals consume the same amount of the energy-related good. This result is in line with the observations by Poterba (1991). He estimates that, with a few exceptions, the expenditure shares of polluting goods decrease at all income deciles as income increases. The regressive nature of the ecotax has also been verified by Bach (2009) for German household data.<sup>5</sup>

## 2.2 The Economic Equilibrium

In an economic equilibrium, the public budgets need to be balanced. Revenue from taxation of the polluting good is given by:

$$\theta_t(2 + n)d(\theta_t) = \theta_t D(\theta_t). \quad (10)$$

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<sup>5</sup>Furthermore, Ekins *et al.* (2011) provide an extensive literature review on this issue which covers nearly all European countries with ecotax reforms.

A share  $\alpha_t \in [0; 1]$  of this revenue and pension contributions by the young have to finance pension benefits of the old. To account for the distortionary nature of pension contributions, we assume that a fraction  $\eta < 1$  of pension contributions is lost during the redistributive process (*e.g.*, Galasso and Profeta, 2007; Cremer *et al.*, 2008). This deadweight loss is larger the less are pension benefits earnings-related (*e.g.*, Conde-Ruiz and Profeta, 2007).<sup>6</sup> The budget constraint of the pension scheme thus amounts to:

$$(1+n)(1-\eta)b_t \int_{y^-}^{y^+} y_{i,t} dF(y_t) + \alpha_t \theta_t D(\theta_t) = \int_{y^-}^{y^+} B(y_{i,t-1}) dF(y_{t-1}). \quad (11)$$

Total pension entitlements of the current old in period  $t$  are fixed<sup>7</sup> and, thus, the pension contribution rate adjusts to satisfy the above budget constraint. Specifically, the pension contribution rate which balances pension benefits and tax revenue can be expressed as:

$$b_t(\theta_t, \alpha_t) = \frac{\bar{B}_t - \alpha_t \theta_t D(\theta_t)}{(1+n)(1-\eta)\bar{y}_t}, \quad (12)$$

where  $\bar{B}_t \equiv \int_{y^-}^{y^+} B(y_{i,t-1}) dF(y_{t-1})$ . For later reference, note that a lower population growth rate leads to less ecotax revenue and lower pension contributions which implies that the pension contribution rate must rise. To see how a higher pollution tax rate affects the pension contribution rate – given pension benefits  $B(y_{i,t-1})$  for all  $i$  are kept constant – we have to determine the sign of the following derivative:

$$\frac{\partial b(\theta_t, \alpha_t)}{\partial \theta_t} = \frac{-\alpha_t (D(\theta_t) + \theta_t D'(\theta_t))}{(1+n)(1-\eta)\bar{y}_t}. \quad (13)$$

The above expression is negative whenever

$$D(\theta_t) + \theta_t D'(\theta_t) = D(\theta_t)(1 - \varepsilon_{D,\theta}) > 0, \quad (14)$$

where  $\varepsilon_{D,\theta} = -D'(\theta_t)\theta_t/D(\theta_t)$  is the demand elasticity of the polluting good with respect to the tax rate. In other words, whenever consumption of the polluting good is inelastic, that is

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<sup>6</sup>The deadweight loss  $\eta$  is related to the Marginal Cost of Public Funds (MCF) for the pension system through  $\eta = 1 - 1/\text{MCF}$ , that is, a higher MCF goes hand in hand with a higher deadweight loss. In the following, we will therefore use the two expressions synonymously. Note that this definition abstracts from administrative costs of taxation since these would also be incurred under the ecotax or a lump-sum tax.

<sup>7</sup>Since the pension scheme is PAYG, pension entitlements are determined by an implicit intergenerational contract, see, *e.g.*, Hammond (1975; pp. 121-124).

smaller than one, the pension contribution rate decreases with the green tax rate. Intuition is straightforward. If by a one percentage increase in the green tax rate aggregate consumption of the dirty good decreases by less than one percent, a positive revenue from taxation is generated. This revenue can be used to reduce the pension contribution rate while keeping pension benefits constant. In the following, we will assume that  $\varepsilon_{D,\theta} < 1$ .<sup>8</sup>

The share  $1 - \alpha_t$  of revenue from environmental taxation is employed to finance the lump-sum transfer  $\tau_t$  to each individual – the young and the old. Thus, we have:

$$(1 - \alpha_t)\theta_t D(\theta_t) = (2 + n)\tau_t \quad \Rightarrow \quad \tau_t(\theta_t, \alpha_t) = \frac{1 - \alpha_t}{2 + n}\theta_t D(\theta_t). \quad (15)$$

Inserting expressions (12) and (15) back into the young's utility function yields their indirect utility function:

$$\begin{aligned} V_{i,t}^Y(\theta_t, \alpha_t) = & \left(1 - \frac{\bar{B}_t - \alpha_t \theta_t D(\theta_t)}{(1 + n)(1 - \eta)\bar{y}_t}\right) y_{i,t} - (p_t + \theta_t)d(\theta_t) + \frac{1 - \alpha_t}{2 + n}\theta_t D(\theta_t) \\ & + u(d(\theta_t)) - h(E(\theta_t)) + \rho V_{i,t+1}^O(\theta_t), \end{aligned} \quad (16)$$

where  $V_{i,t+1}^O(\theta_t)$  denotes indirect utility of a current young in old age. The latter depends on the current green tax rate as pollution in period  $t$  continues to have an effect on damages in the following periods for  $\delta < 1$ . However, it is independent of the share of taxes devoted to the pension scheme in period  $t$  as this share does not affect any future budgets. The old's indirect utility function is given by:

$$V_{i,t}^O(\theta_t, \alpha_t) = B(y_{i,t-1}) + \frac{1 - \alpha_t}{2 + n}\theta_t D(\theta_t) - (p_t + \theta_t)d(\theta_t) + u(d(\theta_t)) - h(E(\theta_t)). \quad (17)$$

The above indirect utility functions of an  $i$ -type young and old can be used to express their preferences for the green tax rate  $\theta_t$  and the share of tax revenue devoted to the pension scheme,  $\alpha_t$ , in an economic equilibrium. Both policy variables are specified in the political process described in Section 4.

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<sup>8</sup>Our assumption on  $\varepsilon_{D,\theta}$  is confirmed by several studies which estimate long-run price elasticities of energy demand, see *e.g.* Hunt and Manning (1989) or Small and Van Dender (2007). Estimates range between 0.1 and 0.9 for different sources of energy. The average long-run elasticity is thereby found to be 0.58 (Espey, 1996).

### 3 Social Optimum

This section analyzes the optimal green tax rate and share of environmental taxes devoted to the pension scheme chosen by a utilitarian social planner. It provides a benchmark against which the properties of the political outcome can be assessed.

At time  $t$ , the social planner accounts for the welfare of all generations from  $t$  to infinity, that is, for the currently old plus all current and future young generations.<sup>9</sup> Using equations (16) and (17), the welfare function can be written as a function of the policy variables of time  $t$ :

$$\mathcal{W}_t(\theta_t, \alpha_t) = \int_{y^-}^{y^+} V_{i,t}^O(\theta_t, \alpha_t) dF(y_{t-1}) + (1+n) \sum_{x=t}^{\infty} ((1+n)\rho)^{x-t} \int_{y^-}^{y^+} V_{i,x}^Y(\theta_t, \alpha_t) dF(y_x). \quad (18)$$

Note that with a utilitarian welfare function and quasi-linear preferences, redistributive considerations within and between generations do not matter – all agents have a constant marginal utility of income equal to one. We assume that the size of the pension system is not open to debate. In other words, the social planner is tied to an implicit contract among successive generations, in which today’s young agree on a transfer to current retirees. The young generation, in turn, expects to be rewarded with a corresponding transfer in their old age.

Differentiating equation (18) with respect to  $\alpha_t$  yields:

$$\frac{\partial \mathcal{W}_t(\theta_t, \alpha_t)}{\partial \alpha_t} = \frac{\eta}{1-\eta} \theta_t D(\theta_t) > 0 \quad \Rightarrow \quad \alpha_t^* = 1. \quad (19)$$

From a normative perspective it is, thus, optimal to devote all tax revenue generated from environmental taxation to the pension scheme. The reason is that a reduction in the pension contribution rate goes hand in hand with a lower deadweight loss compared to a lump-sum replacement of environmental tax revenue. This is equivalent to the ‘weak’ version of the double dividend hypothesis which is relatively uncontroversial, see, *e.g.*, Goulder (1995). It states that passing on tax revenue through cuts in distortionary taxes entails a welfare gain, independent of environmental considerations.

Contrary to  $\alpha_t$ , the tax rate in period  $t$  continues to have an effect on all future generations through consumption of the dirty good in that period and the associated change in the stock

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<sup>9</sup>We do not distinguish between private discount rates used by one generation to discount their remaining lifetime utility and the social discount rate at which the social planner trades off the weighted lifetime utility of different generations. See Schneider *et al.* (2010) on intergenerational trade-offs in models with an infinitely-lived agent and OLG models.

of emissions for  $\delta < 1$ . The first-order condition of (18) with respect to  $\theta_t$  is – after some rearrangements – given by:<sup>10</sup>

$$\frac{\partial \mathcal{W}_t(\theta_t, \alpha_t)}{\partial \theta_t} = \frac{1 - \eta(1 - \alpha_t)}{1 - \eta} D(\theta_t)(1 - \varepsilon_{D,\theta}) - D(\theta_t) - \frac{(2 + n)}{1 - z} h' D'(\theta_t) = 0, \quad (20)$$

where  $z \equiv \rho(1+n)(1-\delta)$  and  $\rho(1+n) < 1$  for the infinite sum of marginal damages to converge to a constant value. Furthermore, the second-order condition with respect to  $\theta_t$ ,  $SOC_{\theta}^*$ , is assumed to be strictly negative (and specified in Appendix A.1). The first term reflects the marginal benefits of higher tax revenue. Revenue from environmental taxation is thereby worth more the more is devoted to the pension scheme as this reduces the existing deadweight loss of pension contributions. The second term captures aggregate marginal costs of green taxes which translate into lower consumption of the dirty commodity in period  $t$ . And, the last expression mirrors the reduction in marginal social costs inflicted on all currently living and future generations when overall consumption of the polluting good declines due to a tax increase in period  $t$ .<sup>11</sup> Rearranging equation (20) and considering that  $\alpha_t^* = 1$ , we have:

$$\theta_t^* = \frac{(2 + n)(1 - \eta)\varepsilon_{D,\theta}h'}{(\varepsilon_{D,\theta} - \eta)(1 - z)} \quad (21)$$

which for non-distortionary pension contributions,  $\eta = 0$ , and no stock pollution,  $\delta = 1$ , is the standard first-best Pigouvian tax rule:  $\theta_t^* = (2 + n)h'$ . That is, the optimal green tax rate  $\theta_t^*$  should be chosen to equal the marginal social damage of the externality. In the second-best, *i.e.*  $\eta > 0$ , the optimal tax rate is additionally adjusted by the marginal costs of public funds and the demand elasticity for the dirty good. As the intuition suggests, higher marginal costs of public funds in the pension scheme thereby increase the attractiveness of green taxes, whereas a higher demand elasticity of the polluting good makes its taxation less appealing. In our OLG framework, an extra term shows up for  $\delta < 1$  as compared to *e.g.* Cremer *et al.* (2008): the optimal green tax rate is additionally adjusted by the term  $h'/(1 - z)$  which is the present value of marginal damages inflicted on all current and future generations. For the green tax rate to be positive, we require  $\varepsilon_{D,\theta} > \eta$ .<sup>12</sup>

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<sup>10</sup>A more detailed derivation of the social optimum can be found in Appendix A.1.

<sup>11</sup>Since  $h'' = 0$  the first-order condition is independent of all future environmental tax rates.

<sup>12</sup>We can assume that this condition holds as it is well-known in the literature that Bismarckian pension schemes bring about a low  $\eta$  (*e.g.*, Conde-Ruiz and Profeta, 2007).

## 4 Majority Voting

In the following, we analyze the majority voting process. In each period, the whole population – the young and old – votes on the green tax rate  $\theta_t$  and on the share of tax revenue devoted to the pension scheme  $\alpha_t$  (repeated voting). Agents' preferences over the two policy parameters are aggregated through a political system of majoritarian voting. Every individual has zero mass, so that no individual vote can change the outcome of the election.

We analyze structure-induced equilibria where agents vote simultaneously but separately on the issues at stake. This idea has been independently developed by Kramer (1972) and Shepsle (1979).<sup>13</sup> In particular, the political system is characterized by the following institutional arrangement:<sup>14</sup>

### Definition 1 (Structure-induced equilibrium)

*A structure-induced equilibrium is characterized by the following conditions:*

- (i) *The electorate – all young and old individuals – constitute the only committee, the Committee of the Whole.*
- (ii) *Each jurisdiction is a single dimension of the issue space, that is, one jurisdiction has the power to set the environmental tax rate,  $\theta_t$ , and another one the share of tax revenue devoted to the pension scheme,  $\alpha_t$ .*
- (iii) *Both jurisdictions are assigned to the Committee of the Whole.*
- (iv) *Amendments to the proposal are permitted only along the dimension that falls in the jurisdiction of the committee, that is, if the proposal regards  $\theta_t$ , only amendments on  $\theta_t$  are permitted, and if it regards  $\alpha_t$ , only amendments on  $\alpha_t$  are permitted.*

In the context of our model, an elected government perfectly represents the preferences of the electorate, the Committee of the Whole (i). The policy issues at stake are assigned to perfectly representative ministries. The share of tax revenue devoted to the pension scheme is determined

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<sup>13</sup>Alternatively, our setting could be framed such that decisions are taken sequentially. The natural first stage would then be the decision on the ecotax rate out of environmental concerns while the utilization of tax revenue would be determined in the second stage. As will be shown later, the ecotax rate in the political equilibrium is independent of  $\alpha_t$  (it only depends on the income of the median voter). Therefore, the outcome of the sequential game coincides with the Kramer-Shepsle equilibrium we describe.

<sup>14</sup>Presentation of the equilibrium concept closely follows Galasso (2008, p. 2161).

by the ministry of finance while the ministry of the environment is accountable for the green tax rate, (ii). In particular, the ministry of environment proposes an ecotax rate for a *given* share of revenue devoted to the pension scheme. Analogously, the ministry of finance suggests a share of revenue devoted to the pension scheme for a *given* environmental tax rate, (iv). Proposals are rooted in the median voter’s preferences of the issue at stake, (iii), and can be thought of as the best responses or reaction functions of the ministries. Their intersection characterizes the structure-induced equilibrium of the voting game where policy proposals of the ministries are mutual best responses to one another. The structure-induced equilibrium, thus, introduces issue-by-issue voting and retains the median voter approach in a multi-dimensional issue space.

This institutional setting is a good description of the German political system where we can observe the same chain of delegation: from voters to elected representatives; from the legislative body (the parliament) to the executive branch, specifically to the head of government (the Chancellor); from the Chancellor to the heads of different executive departments who are – by the German constitution – given the right to carry out their duties independently within the boundaries set by the Chancellor’s political directive (principle of departmentalization, ‘Ressortprinzip’); and finally from the cabinet ministers to civil servants (see, *e.g.*, Schnapp, 2001; Strøm, 2000).

Section 4.1 determines every voter’s ideal point over the environmental tax rate for every given share devoted to the pension scheme,  $\theta_t(\alpha_t)$ , followed by the derivation of the most preferred share of tax revenue devoted to the pension scheme for every given ecotax rate,  $\alpha_t(\theta_t)$ , in Section 4.2. At the end of each section the median voter over  $\theta_t$  and  $\alpha_t$  is identified. Section 4.3 determines the structure-induced equilibrium of the voting game.

#### 4.1 The Green Tax Rate

*The young.* Young individuals find their most preferred green tax rate  $\theta_{i,t}^Y$  for a given  $\alpha_t$  by maximizing their indirect utility function (16) with respect to  $\theta_t$ . The corresponding first-order condition amounts to:

$$\begin{aligned} \frac{\partial V_{i,t}^Y(\theta_t, \alpha_t)}{\partial \theta_t} &= \left( \frac{\alpha_t y_{i,t}}{(1+n)(1-\eta)\bar{y}_t} + \frac{1-\alpha_t}{2+n} \right) D(\theta_t)(1 - \varepsilon_{D,\theta}) - d(\theta_t) \\ &\quad - (1 + \rho(1 - \delta))h'D'(\theta_t) = 0. \end{aligned} \tag{22}$$

The first term in this equation captures the marginal benefit of higher ecotax revenue: the reduction in pension contributions and the higher lump-sum transfer. The second expression reflects the individual's direct costs of higher green taxes. And, the third term represents the reduction in the negative externality (for the lifetime of a young individual) due to lower overall pollution as aggregate consumption of the polluting good decreases with its taxation. The most preferred green tax rate by a young individual  $i$  balances these trade-offs. The second-order condition,  $SOC_\theta^Y$  – specified in the Appendix A.2 – is assumed to be negative for preferences to be single-peaked.

To determine the median voter we have to answer the question how the young's most preferred environmental tax rate changes in income. With the help of the implicit function theorem, we can establish the following result:

$$\frac{\partial \theta_{i,t}^Y}{\partial y_{i,t}} = -\frac{\alpha_t D(\theta_t)(1-\varepsilon_{D,\theta})}{(1+n)(1-\eta)\bar{y}_t SOC_\theta^Y} \geq 0. \quad (23)$$

Thus, higher income goes hand in hand with a higher preferred environmental tax rate if some share of tax revenue is devoted to the pension scheme. The reasoning behind this result is the following. Consumption of the polluting good is independent of income whereas contributions into the pension scheme increase in income. Assume, for example, green taxes reduce the pension contribution rate by 2 percentage points, then, 2 percent of €1,000 are obviously less than 2 percent of €10,000. Hence, a reduction in the pension contribution rate due to higher green taxes benefits high-income individuals more than low-income agents. So, the fact that lower pollution is more desirable for high-income earners does, in our model, not depend on heterogeneous preferences concerning the quality of the environment or the polluting good. All individuals are equally affected by pollution. Instead, individuals with higher income have a preference for generating more revenue via environmental taxes if this revenue is (partly) passed on to the pension scheme.

*The old.* Old agents find their most preferred green tax rate  $\theta_{i,t}^O$  by maximizing their indirect utility function (17) with respect to  $\theta_t$ . The corresponding first-order condition reads as follows:

$$\frac{\partial V_{i,t}^O(\theta_t, \alpha_t)}{\partial \theta_t} = (1 - \alpha_t)d(\theta_t)(1 - \varepsilon_{D,\theta}) - d(\theta_t) - h'D'(\theta_t) = 0. \quad (24)$$

The first difference to the first-order condition determining the young's most preferred tax rate

is that the positive effect of higher green taxes on pension contributions is missing. Hence, the old's most preferred environmental tax rate is independent of their income implying that all old vote for the same green tax rate. The second difference is that the old generation wants to internalize less of the marginal damage as they do not live in the next period any more. Again, the second-order condition  $SOC_\theta^O$  is assumed to hold for preferences to be single-peaked.

We are now able to compare the preferred tax rates of the old and young generation and can establish the following Lemma.

**Lemma 1 (Comparison of the old's and young's preferred tax rates)**

*Evaluating the old's first-order condition, equation (24), at the most preferred green tax rate of the young generation, equation (22), we get:*

$$\left. \frac{\partial V_{i,t}^O(\theta_t)}{\partial \theta_t} \right|_{\theta_{i,t}^Y} = -\frac{\alpha_t D(\theta_t)(1 - \varepsilon_{D,\theta})y_{i,t}}{(1+n)(1-\eta)\bar{y}_t} + \rho(1-\delta)h'D'(\theta_t) < 0 \quad \forall y_{i,t}. \quad (25)$$

The young generation thus prefers a higher green tax rate compared to the old generation for two reasons. First, the young benefit – for a positive  $\alpha_t$  – from the reduction in the pension contribution rate, whereas pension benefits of the old generation are unaffected by the green tax. Second, the young generation is hit more by environmental damage than the old, because they live longer and incur disutility from the stock of pollution also in the second part of their lives. More importantly, even though the young generation would still prefer a weakly higher tax rate than the old if all revenue were refunded lump-sum, the young's preferred ecotax rate would not rise with income anymore.

When voting on environmental taxes for a given  $\alpha_t$ , agents can be ordered according to their age and income as illustrated in Figure 1.<sup>15</sup> As long as  $n > 0$ , it follows that there are always more young (working) agents than old (retired) individuals. This implies that the median voter – the pivot in determining the political outcome of majority voting – is a young type  $i$  individual who divides the electorate in halves. Specifically, the median voter is determined through

$$1 + (1+n)F(y_t^M) = \frac{2+n}{2} \Leftrightarrow F(y_t^M) = \frac{n}{2(1+n)}. \quad (26)$$

As can be easily verified, a lower population growth rate goes hand in hand with a lower income

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<sup>15</sup>For  $\alpha_t = 0$ , the straight line,  $\theta_{i,t}^Y(\alpha_t)$ , in the right quadrant of the diagram would be flat.

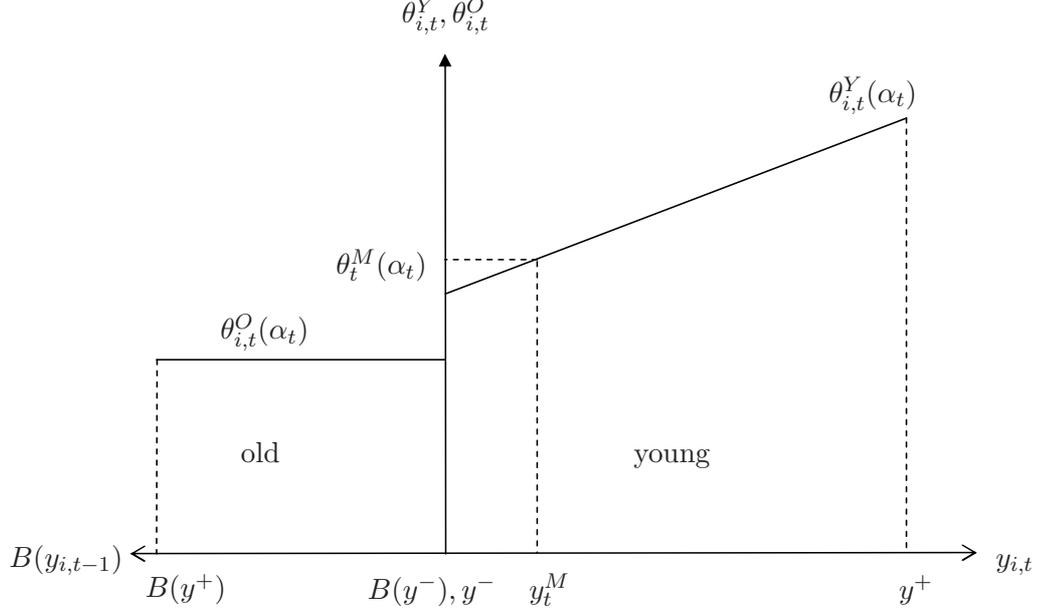


Figure 1: Political Equilibrium for  $\alpha_t > 0$ .

of the median voter.

## 4.2 The Budgetary Rule

*The young.* The young generation finds their most preferred share of green tax revenue devoted to the pension scheme by maximizing indirect utility, equation (16), with respect to  $\alpha_t$ . Individual  $i$ 's first-order condition amounts to:

$$\frac{\partial V_{i,t}^Y(\theta_t, \alpha_t)}{\partial \alpha_t} = \left( \frac{y_{i,t}}{(1+n)(1-\eta)\bar{y}_t} - \frac{1}{2+n} \right) \theta_t D(\theta_t) \stackrel{\geq}{\leq} 0. \quad (27)$$

The above equation can be positive or negative. It is positive if the benefit due to lower pension contributions (first term in brackets) exceeds the benefit of a lump-sum transfer (second term). As explained earlier, the advantage of lower pension contributions increases in income. The critical income  $\tilde{y}_t$  below which a young individual prefers that all green tax revenue is given back in a lump-sum way is defined by:

$$\tilde{y}_t \equiv \frac{1+n}{2+n} (1-\eta)\bar{y}_t. \quad (28)$$

The young's most preferred share of environmental taxes devoted to the pension scheme is thus given by

$$\begin{aligned} \alpha_t^Y(\theta_t) &= 0 & \text{if } & y_{i,t} < \tilde{y}_t, \\ \alpha_t^Y(\theta_t) &= 1 & \text{if } & \tilde{y}_t \leq y_{i,t}. \end{aligned} \tag{29}$$

*The Old.* Maximizing the old's indirect utility function, equation (17), with respect to  $\alpha_t$ , yields the following first-order condition:

$$\frac{\partial V_{i,t}^O(\theta_t, \alpha_t)}{\partial \alpha_t} = -\theta_t d(\theta_t) < 0 \quad \Rightarrow \quad \alpha_t^O(\theta_t) = 0. \tag{30}$$

As the old do not benefit from a reduction in the pension contribution rate they want all revenue from environmental taxation – independent of the size of the green tax rate – given back in a lump-sum way.

To sum up our findings in this section, we conclude with the following Lemma.

**Lemma 2 (Comparison of the old's and young's preferred budgetary rule)**

*Old individuals and young individuals with low income ( $y_{i,t} < \tilde{y}_t$ ) prefer redistribution of tax revenue via a lump-sum transfer whereas higher income earners ( $y_{i,t} \geq \tilde{y}_t$ ) vote for a reduction of pension contributions.*

Thus, although the weak double dividend would materialize if all tax revenue were refunded through reductions in pensions contributions as in the social optimum, old individuals and young individuals with low income benefit more from lump-sum replacement of tax revenue and will therefore not support revenue recycling via the pension scheme.

Again, voters can be ordered according to age and income, and the median voter is determined by equation (26). Independent of the dimension under consideration, he is of the young generation with below average income.

**4.3 The Political Equilibrium**

In the previous sections we identified the median voter for each policy dimension whose income is determined by equation (26). As argued above, the most preferred policies of the median voter –  $\theta_t^M(\alpha_t)$  and  $\alpha_t^M(\theta_t)$  – can be interpreted as reaction functions. Their intersection yields the structure-induced equilibrium  $(\theta_t^{eq}, \alpha_t^{eq})$ .

First, assume the median voter's income is such that  $y_t^M < \tilde{y}_t$ . In this case  $\alpha_t^{eq} = 0$ . The green tax rate in the political equilibrium is then implicitly determined through:

$$-\varepsilon_{D,\theta}d(\theta_t) - [1 + \rho(1 - \delta)]h'D'(\theta_t) = 0. \quad (31)$$

Evaluation of the social planner's first-order condition with respect to  $\theta_t$ , equation (20), at equation (31) yields:

$$\left. \frac{\partial \mathcal{W}(\theta_t, \alpha_t = 1)}{\partial \theta_t} \right|_{\theta_t^{eq}, \alpha_t^{eq} = 0} = D(\theta_t) \left( \frac{\varepsilon_{D,\theta}}{(1-z)(1+\rho(1-\delta))} + \frac{\eta - \varepsilon_{D,\theta}}{1-\eta} \right) > 0. \quad (32)$$

The above equation is always positive, implying  $\theta_t^* > \theta_t^{eq}$  for  $\alpha_t^{eq} = 0$ .<sup>16</sup> The reason for this result is as follows. If all environmental taxes are given back in a lump-sum fashion,  $\alpha_t^{eq} = 0$ , the green tax rate chosen in the political process does not account for efficiency losses induced by the pension scheme. The social planner, by contrast, takes into consideration that higher green taxes reduce the deadweight loss caused by pension contributions. Furthermore, for  $\delta < 1$ , he also takes the effect of today's pollution on all future generations into account and not only the future damage inflicted on the currently living young generation.

Now, assume  $\tilde{y}_t \leq y_t^M$  implying  $\alpha_t^{eq} = 1$ . The ecotax rate in the political equilibrium is then implicitly determined through

$$\frac{y_t^M}{(1+n)(1-\eta)\tilde{y}_t} D(\theta_t)(1 - \varepsilon_{D,\theta}) - d(\theta_t) - [1 + \rho(1 - \delta)]h'D'(\theta_t) = 0. \quad (33)$$

Again, we evaluate the social planner's first-order condition with respect to  $\theta_t$  at this equation:

$$\begin{aligned} \left. \frac{\partial \mathcal{W}(\theta_t, \alpha_t = 1)}{\partial \theta_t} \right|_{\theta_t^{eq}, \alpha_t^{eq} = 1} &= \left( 1 - \frac{2+n}{1+n} \frac{y_t^M}{\tilde{y}_t} \right) \frac{D(\theta_t)(1 - \varepsilon_{D,\theta})}{1-\eta} \\ &\quad - (2+n)h'D'(\theta_t) \frac{\rho(1-\delta)(z+n)}{1-z} \stackrel{?}{\geq} 0. \end{aligned} \quad (34)$$

The sign of the above equation is now no longer determinate, and the median voter's preferred green tax rate may well be close or even *above* the tax rate chosen by the social planner. We name the first term on the right-hand side '*political economy effect*' and the second '*environmental sustainability effect*'. Unless  $\delta = 1$ , the latter effect is always strictly positive as the social

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<sup>16</sup>In Appendix A.3.1 we show in more detail that the above equation is of positive sign.

planner internalizes more of the environmental damage accruing in the future while the first effect is ambiguous in sign. The political economy effect may thus drag the tax rate chosen in the political equilibrium above the optimal tax rate. Assume for a moment that  $\delta = 1$ , then, emissions do not accumulate in the atmosphere and the second term drops out. Using equation (28), we have:

$$\theta_t^* \begin{matrix} \geq \\ < \end{matrix} \theta_t^{eq} \Leftrightarrow 1 \begin{matrix} \geq \\ < \end{matrix} \frac{2+n}{1+n} \frac{y_t^M}{\bar{y}_t} \Leftrightarrow y_t^M \begin{matrix} \leq \\ > \end{matrix} \frac{\tilde{y}_t}{1-\eta}. \quad (35)$$

The median voter's environmental tax rate lies above the adjusted Pigouvian tax rate whenever his income exceeds the critical income  $\tilde{y}_t$  by the factor  $1/(1-\eta)$ .

The reasoning behind this result can best be understood by comparing the social planner's and median voter's first-order conditions with respect to  $\theta_t$ . For  $\delta = 1$  and  $\alpha_t = 1$ , equations (20) and (22) reduce to:

$$\frac{1}{1-\eta} D(\theta_t)(1-\varepsilon_{D,\theta}) - (2+n)h'D'(\theta_t) - (2+n)d(\theta_t) = 0 \quad (36)$$

$$\frac{1}{1-\eta} D(\theta_t)(1-\varepsilon_{D,\theta}) \frac{y_t^M}{\bar{y}_t} \frac{1}{1+n} - h'D'(\theta_t) - d(\theta_t) = 0. \quad (37)$$

The first two terms in each equation represent the marginal benefits of a tax increase due to revenue recycling through the pension system and due to the reduction of environmental damages. The third terms illustrate the marginal costs of higher ecotaxes. As the median voter does not take into account that all other individuals are also affected by changes in the green tax rate, he underestimates *both* benefits and costs compared to the social planner.<sup>17</sup> While the underestimation of marginal costs raises the tax rate in the political equilibrium, the underestimation of marginal benefits lowers the tax rate. A graphical illustration is given in Appendix A.3.2. Higher income of the median voter thereby makes the latter effect less severe as can be seen from the first term in the second line. Note that only the combined underestimation of benefits and costs makes the overall effect ambiguous in sign. In other words, although the median voter tends to vote for a higher green tax rate because he does not consider that the costs of higher taxes are borne by all, an inefficiently high tax rate can only prevail in the political equilibrium if marginal benefits are not underestimated too much by the median voter. This happens whenever the median voter's income is sufficiently high. Otherwise, the politically

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<sup>17</sup>Note that  $y_t^M < (1+n)\bar{y}_t$ .

induced tax rate is inefficiently low in equilibrium.

For  $\delta < 1$ , the median voter still desires an inefficiently high tax rate if his income is high enough so as to outweigh the environmental sustainability effect. The following Proposition summarizes our results for the outcome of the political process.

**Proposition 1 (Political equilibrium and comparison to the social optimum)**

For  $n > 0$ , the median voter is a young individual and

(i) the equilibrium share of taxes devoted to the pension scheme,  $\alpha_t^{eq}$ , is

$$\begin{aligned} \alpha_t^{eq} &= 0 & \text{for } & y_t^M < \tilde{y}_t, \\ \alpha_t^{eq} &= 1 & \text{for } & y_t^M \geq \tilde{y}_t. \end{aligned}$$

(ii) the equilibrium tax rate,  $\theta_t^{eq}$ , for  $\delta = 1$  is

$$\begin{aligned} \theta_t^{eq} &\leq \theta_t^* & \text{for } & y_t^M \leq \tilde{y}_t/(1-\eta), \\ \theta_t^{eq} &> \theta_t^* & \text{for } & y_t^M > \tilde{y}_t/(1-\eta). \end{aligned}$$

(iii) the equilibrium tax rate for  $\delta < 1$  exceeds the first-best tax rate if  $y_t^M > \tilde{y}_t/(1-\eta)$  and if the median voter's income is sufficiently high such that the political economy effect outweighs the environmental sustainability effect.

Our results are driven by demography, income distribution, the tax-price elasticity of the polluting good as well as the parameters  $\rho$ ,  $\delta$  and  $\eta$ .<sup>18</sup> Whether we can observe an inefficiently high or low tax rate in reality is thus an empirical question which we try to answer in Section 6.

## 5 Demographic Change

Demography plays an important role in our model. Not only does demography directly affect the political outcome in that it determines the median voter, it also indirectly affects the political outcome in that it changes individuals' preferences. In this section, we analyze the impact of a changing  $n$  on the desired tax rates of the median voter and the social planner. As Germany is

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<sup>18</sup>Note that one can rearrange equation (34) such that  $h'$  drops out. Thus, the comparison of tax rates is independent of the size of marginal damages as long as the second-order conditions specified in the Appendix hold.

confronted with a dramatic population aging, we concentrate on the effects of a decreasing  $n$ . Applying the implicit function theorem to equations (21), (22) and (24), we can establish the following Lemma.

**Lemma 3 (Tax rates and demographic change)**

*The following conditions hold for the desired tax rates of all individuals and the social planner:*

$$\frac{\partial \theta_t^*}{\partial n} = \frac{h' D'(\theta_t)(1 + \rho(1 - \delta))/(1 - z)^2}{SOC_\theta^*} > 0, \quad (38)$$

$$\frac{\partial \theta_{i,t}^O}{\partial n} = \frac{h' d'(\theta_t)}{SOC_\theta^O} > 0, \quad (39)$$

$$\frac{\partial \theta_{i,t}^Y}{\partial n} = \frac{h' d'(\theta_t)[1 + \rho(1 - \delta)] + \frac{\alpha_t y_{i,t}^Y}{(1 + n)^2(1 - \eta)\bar{y}_t} d(\theta_t)(1 - \varepsilon_{D,\theta})}{SOC_\theta^Y} \gtrless 0. \quad (40)$$

Obviously, a lower population growth rate decreases the optimal ecotax as less of the environmental damage needs to be internalized. A similar reasoning applies to the old's and young's preferred tax rates. With a lower  $n$ , both desire a lower ecotax as otherwise the same environmental damage would affect less individuals. If, however, at least some tax revenue is used to cut pension contributions ( $\alpha_t > 0$ ), a second effect shows up in equation (40) which makes a young type  $i$ 's reaction to a decrease in  $n$  ambiguous. To see the intuition behind this effect, we differentiate equation (13) with respect to  $n$ ,  $\partial^2 b(\theta_t, \alpha_t)/\partial \theta_t \partial n > 0$ , that is, a lower  $n$  (higher  $b_t$ ) makes tax increases more effective in reducing pension contributions for given pension benefits and increases the attractiveness of the ecotax rate.<sup>19</sup> Hence, for  $\alpha_t > 0$ , the young's preferred ecotax may rise or fall, depending on the relative strength of the effects at work.

We are now ready to determine how the ecotax rate in the political equilibrium is affected by a marginal change in  $n$ . Suppose that the median voter is originally one with income  $y_t^M < \tilde{y}_t$ . Then  $\alpha_t^{eq} = 0$  at the beginning. If  $n$  decreases, we have by Lemma 3 that the politically induced tax rate decreases as well – given that the median voter's income remains unchanged. However, a decrease in the population growth rate additionally increases the share of the old. Hence, the

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<sup>19</sup>To keep the pension scheme solvent over the long term, the so-called demographic 'sustainability factor' was introduced in 2005. In determining pension benefits, the German pension formula now takes into account the number of pensioners relative to the number of contributors. Specifically, population aging not only affects the young in that it increases pension contributions, but also reduces pension benefits of the current old. Introducing the demographic sustainability factor in our analysis would thereby reduce the attractiveness of higher ecotaxes due to population aging for the young in society.

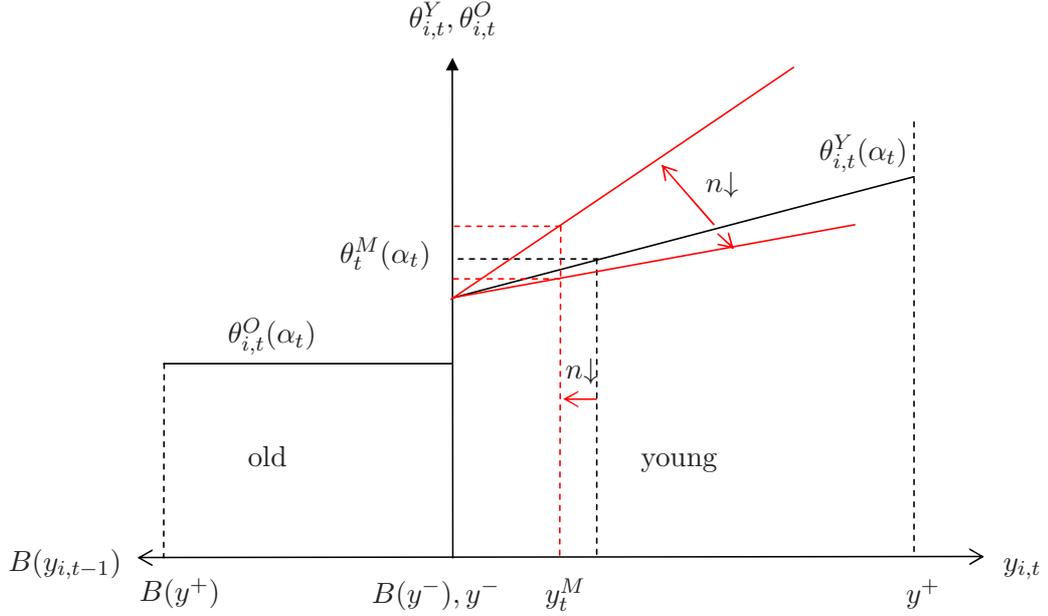


Figure 2: Demographic change for  $\alpha_t > 0$ .

median voter shifts to a young agent of lower income. This effect only contributes to the first effect as lower income individuals prefer lower tax rates. If the initial equilibrium is given by  $y_t^M > \tilde{y}_t$ , implying  $\alpha_t^{eq} = 1$ , Lemma 3 predicts an ambiguous effect of the median voter's desired tax rate to a change in  $n$ , given that his income stays the same. Again, the median voter changes to an individual with lower income. Consequently, the equilibrium tax rate may either rise or fall. Figure 2 illustrates our findings.

In addition to the effects described above, the threshold income  $\tilde{y}_t$  becomes smaller as  $\partial \tilde{y}_t / \partial n = (1 - \eta) \bar{y}_t / (2 + n)^2 > 0$ . Thus population aging makes it more likely that the equilibrium share of tax revenue devoted to the pension scheme changes to  $\alpha_t^{eq} = 1$  for a marginal decrease in  $n$ .

Whether a demographic change as expected for Germany will change the political equilibrium will be analyzed in the following section.

## 6 A Calibration of the Model

In this section, we calibrate our model to the German economy and inspect which refund rule is preferred by the median voter and whether the German ecotax rate is larger or smaller than the optimal tax rate. Computations are undertaken for the year 2009 where the last elections to the Bundestag took place and for the year 2050. Data for the gross labor income distribution

of households are taken from the EVS (Sample Survey of Income and Expenditure) from the Federal Statistical Office in Germany. Data on population size are obtained from the OECD database.

We find  $\bar{y}_{2009} = \text{€}2,971$  and  $n = 1.33$ . To compute the latter, we subtracted the non-working young from the total population size. This leaves us with 68,372,750 individuals of whom 20,531,020 are above the age of 65. This corresponds to a pensioner/contributor ratio of 0.43. With equation (26), we have  $F(y_{2009}^M) = 28.5$  which yields  $y_{2009}^M = \text{€}2,229$ . Kleven and Kreiner (2006) estimate for Germany the marginal costs of public funds to be 1.55 for a proportional tax change. For our modelling framework, this implies an  $\eta$  of 0.35. Since pension benefits in Germany are to a large extent earnings-related, the deadweight loss associated with the pension system is known to be smaller than for general income taxes. Thus, this value can be seen as an upper limit. The critical income below which the young want all ecotax revenue to be given back in a lump-sum fashion is then given by  $\tilde{y}_{2009} = \frac{1+1.33}{2+1.33}(1 - 0.35)\text{€}2,971 = \text{€}1,351$ . By equation (29), it is indeed optimal for the median voter to vote for earmarking of the ecotax revenue as reductions in pension contributions.<sup>20</sup> Additionally, the data reveal that for no stock pollution, we have  $\frac{\tilde{y}_{2009}}{1-\eta} = \text{€}2,079 < y_{2009}^M$  and, by Proposition 1,  $\theta_{2009}^* < \theta_{2009}^{eq}$ . In other words, for  $\delta = 1$ , the green tax rate chosen in the political process exceeds the green tax rate chosen by the social planner.

The IPCC 2001 Technical Report estimates the atmospheric lifetime of  $CO_2$  to be 5 to 200 years. While a decay rate equal to one can be justified with a lifetime of 5 years, this is no longer the case if  $CO_2$  stays in the atmosphere for 200 years. We, thus, compute the difference between the optimal and preferred green tax rate by the median voter for different decay rates. Note that once we relax the assumption of no stock pollution, parameter values for the demand elasticity of the polluting good and the discount rate are additionally of relevance. While estimates for the long-run elasticity for gasoline can be found in the literature, it is less clear-cut which discount rate to employ. Studies by Nordhaus and Boyer (2000) use a discount rate of 3% per year while in the well-known Stern report a discount rate as low as 0.1% per year was employed.<sup>21</sup> For our

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<sup>20</sup>Note that even for  $\eta = 0$ , it would be optimal for the median voter to employ all green tax revenue for a reduction in pension contributions.

<sup>21</sup>Stern (2007) takes a normative stance on discounting, justifying the positive time discount rate with the low probability that society becomes extinct. Other authors such as Broome and Schmalensee (1992) or Cline (1992) reject positive discount rates on ethical grounds. Contrary to that, Nordhaus (2007), for instance, argues that information on intertemporal preferences can be inferred from observations of investment decisions on capital markets and, therefore, a positive discount rate can be employed.

	$\eta = 0.35; \varepsilon_{D,\theta} = 0.58$		$\eta = 0.35; \varepsilon_{D,\theta} = 0.4$		$\eta = 0.15; \varepsilon_{D,\theta} = 0.58$	
$\rho$	0.2	0.4	0.2	0.4	0.2	0.4
$\delta: 0$	$\theta^* > \theta^{eq}$	$\theta^* > \theta^{eq}$	$\theta^* < \theta^{eq}$	$\theta^* > \theta^{eq}$	$\theta^* > \theta^{eq}$	$\theta^* > \theta^{eq}$
0.2	- " -	- " -	- " -	$\theta^* < \theta^{eq}$	- " -	- " -
0.4	- " -	- " -	- " -	- " -	- " -	- " -
0.6	$\theta^* < \theta^{eq}$	- " -	- " -	- " -	- " -	- " -
0.8	- " -	$\theta^* < \theta^{eq}$	- " -	- " -	$\theta^* < \theta^{eq}$	- " -
1.0	- " -	- " -	- " -	- " -	- " -	$\theta^* < \theta^{eq}$

Table 1: Comparison between  $\theta^*$  and  $\theta^{eq}$  for the year 2009.

analysis, we therefore make use of two different values of the discount factor  $\rho \in \{0.2; 0.4\}$ .<sup>22</sup> As a starting point, we assume  $\varepsilon_{D,\theta} = 0.58$  which is the average long-run demand elasticity for gasoline found in different studies (see Espey, 1996).

Table 1 illustrates our results. Our simulations show that a larger difference between  $\eta$  and  $\varepsilon_{D,\theta}$  (columns 1, 2, 5 and 6) implies that the natural decay and removal rate must be rather high ( $\delta > 0.5$ ) for the median voter tax rate to be inefficiently high while this happens already at lower decay rates for a comparably small difference (column 3 and 4). The higher discount factor implies that the utility of future generations is discounted less, shifting the switching point between inefficiently low and high politically induced tax rates to the next higher decay rate (columns 2, 4 and 6). In these cases, the parameter space for which the social planner chooses higher tax rates than the median voter naturally widens. However, the impact of the discount factor on our results can be seen as rather limited. Finally, the less stock of  $CO_2$  accumulates in the atmosphere, the likelier is it that the median voter's preferred tax rates are close to the social optimum or inefficiently high as the social planner then needs to internalize less environmental damage affecting future generations. Consequently, the fiscal effects through the pension system weigh comparatively more.

Population projections by the Federal Statistical Office in Germany uncover that  $n = 0.55$  for the year 2050, corresponding to a pensioner/contributor ratio of 0.65. How does this population shrinking affect our results concerning the political sustainability of Germany's green tax

<sup>22</sup>Here, one period of time is equal to 50 years. The corresponding discount rates for  $\rho = 0.2$  and  $\rho = 0.4$  are 3.2% and 1.8%.

rate? Assume that the income distribution remains constant, then,  $F(y_{2050}^M) = 0.18$  implying  $y_{2050}^M = \text{€}1,346$ . The critical income below which a young agent wants the ecotax revenue to be given back in a lump-sum fashion is then  $\tilde{y}_{2050} = \frac{1+0.55}{2+0.55}(1 - 0.35)\text{€}2,971 = \text{€}1,174$ . Thus, even with this dramatic population aging, the median voter still finds it profitable to employ all ecotax revenue to cut pension contributions. However, Proposition 1 reveals that the median voter's income is now too low ( $y_{2050}^M < \frac{\tilde{y}_{2050}}{1-\eta} = \text{€}1,806$ ) to drag the most preferred green tax rate above the optimal green tax rate, that is  $\theta_{2050}^* > \theta_{2050}^{eq}$  for the parameter values used above.

## 7 Discussion

The previous sections have shown that the ecotax rate in the political equilibrium lies always below its efficient level whenever population growth is positive and all ecotax revenue is given back in a lump-sum fashion. Higher than or close to efficient tax rates only prevail under majority voting if some share of tax revenue is devoted to the pension scheme. As Proposition 1 states, this is the likelier the more income the median voter has at its disposal. Put another way, only the linking of the pension scheme to the ecotax package allows for higher ecotax rates in political equilibrium. The second instrument, the budgetary rule, opens the possibility to 'buy' political support for a higher ecotax from young voters. This possibility would not arise if the refunding rule were restricted to lump-sum redistribution or extra public spending which would benefit all generations alike. In Cremer *et al.* (2004), the constitutional planner is able to implement the efficient tax rate in the voting stage by choosing an appropriate refund rule in the first stage which is not subject to voting. Our positive analysis of both instruments suggests that the refund rule is – under certain conditions – able to reduce the overall distortion in the economy which is due to environmental and fiscal externalities. Along these lines, the double dividend argument has politico-economic implications because it may go along with more support for higher ecotaxes.<sup>23</sup> A similar argument is given by Aidt (2010) who also finds that the endogenous choice of a refund rule may render higher ecotax rates politically more acceptable.<sup>24</sup>

The key to our results is the redistribution of ecotax revenue to young voters who are – for positive population growth – decisive in the political process. They support higher ecotaxes, *inter*

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<sup>23</sup>Empirical and experimental studies examining public support for taxation have mainly focused on transport-related taxes, see, *e.g.*, Schuitema and Steg, 2008, or Sælen and Kallbekken, 2011. For a study on tax aversion and revenue recycling in the lab see Kallbekken, 2011.

<sup>24</sup>For an extensive review of the political economy of instrument choice in environmental policy see Aidt, 2012.

*alia*, because they benefit from reductions in pension contributions, but they would similarly gain from reductions in personal income or other social security taxes which are levied proportionally or overproportionally to income. Such policies favor young working individuals – the more so the more progressive these systems are – while the old generation is largely unaffected. As already mentioned in the introduction, ecotax reforms of this kind were carried out in Sweden, Denmark, the Netherlands and the UK. In our theoretical model, the pension contribution rate could more generally be interpreted as personal income tax rate, and instead of holding pension benefits constant, total government spending could be kept fixed. An increase in the ecotax would then again prove more advantageous for young individuals, in particular high-income earners, than for retirees if not all ecotax revenue is distributed back lump-sum. Therefore, our model could well be applied – with only minor modifications – to other European countries and provides some evidence that distributing revenue generated by environmental regulation to young agents might be a promising strategy to secure political support for higher ecotaxes.

Since generations are dynastically linked and since today's consumption of the dirty good also affects the offspring of each generation, that is, its children, children's children and so on, a more adequate representation of preferences may be to explicitly incorporate intergenerational altruism (see, *e.g.*, Barro, 1974). Then, today's old would not only derive utility from their own consumption but also from all future generations' utility levels. How would such intergenerational altruism change the political equilibrium? First, note that the old's indirect utility then also depends on the young's income. The most preferred green tax rate is no longer constant across the old generation but increases in the children's income. Parents having offspring who earns high income thus vote for higher green taxes as compared to those with children who earn less. They may also prefer earmarking of ecotax revenue to the pension scheme instead of lump-sum transfers. But, more importantly, the currently old and young generation internalize the externality of their dirty good consumption on all future generations. This increases the most preferred green tax rate of both generations and thus also of the median voter who may now be either a young and/or an old individual. Nevertheless, the *intragenerational* externality remains and if altruism is only one-sided, the young do not internalize the impact of their dirty good consumption on their parents' utility. In other words, the political equilibrium may still be different from the social optimum<sup>25</sup>, but compared to no altruism it yields a higher green

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<sup>25</sup>To avoid double-counting, the altruistic component should not enter the welfare function which implies that the social optimum remains unaffected from altruistic preferences (see, *e.g.*, Hammond, 1987).

tax rate and, for given parameter constellations, it becomes more likely that ecotax revenue is earmarked to the pension scheme.

Our theoretical model comprises two periods for each generation, implying that all young agents are of the same age. In reality, however, a young individual approaching pension age may anticipate the effects of his vote on his welfare in old age and therefore vote differently compared to a young agent who just entered working life, particularly if the next elections do not come up soon. Sinn and Uebelmesser (2003) find that, in Germany, the median voter is approximately of age 48 around 2009 and of age 53 around 2030. Breaking down the lifetime of each generation in our model by introducing different age cohorts, this aging of the median voter would reduce the attractiveness of higher green taxes in the political equilibrium. On the other hand, though, working individuals close to their retirement age also have higher incomes due to the income profile which typically rises with experience and age. This would counteract the first effect of aging, indicating that our results are robust.

## 8 Concluding Remarks

We have analyzed the political determination of the German ecotax package both theoretically and empirically. In the OLG model we employ, voters have different preferences with respect to the ecotax reform, due to income and, more importantly, due to age. We found that old individuals prefer lower tax rates than young individuals as they do not benefit from a reduction in pension contributions and do not suffer from environmental damage in the future. Furthermore, both old individuals and young low-income earners vote for full lump-sum redistribution of tax revenue. High-income earners, however, benefit more from a reduction of pension contributions than from lump-sum transfers because consumption of the externality-generating good is independent of income while pension contributions are proportional to income.

For a positive population growth, the median voter over both dimensions was found to be identical and of the young generation. The environmental tax rate in the political equilibrium can be higher or lower than the efficient tax rate (or incidentally coincide with it), depending mainly on demography and income distribution. While the social planner would choose a share of tax revenue devoted to the pension scheme equal to unity so as to reduce the deadweight loss from pension contributions, this share was shown to be either zero or unity in the political equilibrium.

The calibration of the model gives a flavor of the situation in Germany. First, it is indeed optimal for the median voter to choose a reduction of pension contributions rather than a lump-sum transfer. Second, for reasonable parameter values, the German ecotax may well lie close to or above its optimal level. This is the likelier the more  $CO_2$  is degraded and removed in the atmosphere within the lifetime of one generation, and the lower the difference between the deadweight loss caused by distortionary pension contributions and the tax-price elasticity of the dirty good. Further demographic change in Germany towards a ‘gerontocracy’ threatens to lower the politically induced tax rate below its optimal level, starting from a tax rate which is either inefficiently high or already inefficiently low. This is because the median voter may not dispose of sufficiently high income in the future anymore to keep the tax rate above or close to the social optimum.

## A Technical Appendix

### A.1 Derivation of Social Optimum

We can rewrite equation (18) by splitting up the last term into the utility of the currently young and the sum of utilities of all future (young) generations:

$$\begin{aligned} \mathcal{W}_t(\theta_t, \alpha_t) &= \int_{y^-}^{y^+} V_{i,t}^O(\theta_t, \alpha_t) dF(y_{t-1}) \\ &+ (1+n) \left[ \int_{y^-}^{y^+} V_{i,t}^Y(\theta_t, \alpha_t) dF(y_t) + \sum_{x=t+1}^{\infty} ((1+n)\rho)^{x-t} \int_{y^-}^{y^+} V_{i,x}^Y(\theta_t) dF(y_t) \right], \end{aligned}$$

where the utilities of all future generations do not depend on  $\alpha_t$ . This implies that for these generations only marginal damages from emissions remain in the first-order condition below.

Taking the derivative with respect to the tax rate, we then have:

$$\begin{aligned} \frac{\partial \mathcal{W}_t(\theta_t, \alpha_t)}{\partial \theta_t} &= \frac{1 - \eta(1 - \alpha_t)}{1 - \eta} D(\theta_t)(1 - \varepsilon_{D,\theta}) - D(\theta_t) - (2+n)h'D'(\theta_t) - zh'D'(\theta_t) \\ &- (1+n)[1 + \rho(1 - \delta)]h'D'(\theta_t) \sum_{x=t+1}^{\infty} z^{x-t} = 0. \end{aligned}$$

Carrying out an index transformation and assuming that  $\rho(1+n) < 1$  as  $\sum_{t=0}^{\infty} [\rho(1+n)]^t = 1/[1 - \rho(1+n)]$  only converges for the argument being less than unity, yields equation (20).

The second-order condition with respect to the tax rate is as follows:

$$SOC_{\theta}^* = \frac{1 - \eta(1 - 2\alpha_t)}{1 - \eta} D'(\theta_t) + \left( \frac{1 - \eta(1 - \alpha_t)}{1 - \eta} \theta_t - \frac{2 + n}{1 - z} h' \right) D''(\theta_t), \quad (41)$$

where  $D''(\theta_t) = (2 + n)d''(\theta_t) = -(2 + n)\frac{u'''}{(u'')^3} > 0$ . The second-order condition is strictly negative for  $h'$  sufficiently large.

## A.2 Single-Peakedness

The second-order conditions of equations (22) and (24) are given by

$$\begin{aligned} SOC_{\theta}^Y &= 2\Omega D'(\theta_t) - d'(\theta_t) + (\Omega\theta_t - [1 + \rho(1 - \delta)]h') D''(\theta_t), \\ SOC_{\theta}^O &= (1 - 2\alpha_t)d'(\theta_t) + \left( \frac{1 - \alpha_t}{2 + n} \theta_t - h' \right) D''(\theta_t), \end{aligned} \quad (42)$$

where  $\Omega \equiv \frac{\alpha_t y_{i,t}}{(1+n)(1-\eta)\tilde{y}_t} + \frac{1-\alpha_t}{2+n} > 0$  and  $D''(\theta_t) = (2+n)d''(\theta_t) = -(2+n)\frac{u'''}{(u'')^3} > 0$ . Furthermore,  $\frac{1-\alpha_t}{2+n}\theta_t - h' = \frac{\alpha_t d(\theta_t)}{D'(\theta_t)} < 0$  by the first-order condition (22). Both conditions are negative if  $h'$ , the marginal damage from the polluting good, is sufficiently large.

## A.3 Comparison of $\theta_t^*$ and $\theta_t^{eq}$

### A.3.1 $y_t^M < \tilde{y}_t$

$$\begin{aligned} \left. \frac{\partial \mathcal{W}(\theta_t, \alpha_t = 1)}{\partial \theta_t} \right|_{\theta_t^{eq}, \alpha_t^{eq} = 0} &= D(\theta_t) \left( \frac{\varepsilon_{D,\theta}}{(1-z)(1+\rho(1-\delta))} + \frac{\eta - \varepsilon_{D,\theta}}{1-\eta} \right) \\ &= D(\theta_t) \frac{(\eta - \varepsilon_{D,\theta})(1-z)(1+\rho(1-\delta)) + \varepsilon_{D,\theta}(1-\eta)}{(1-\eta)(1-z)(1+\rho(1-\delta))} \end{aligned}$$

The above equation is positive for  $\frac{\varepsilon_{D,\theta}(1-\eta)}{\varepsilon_{D,\theta}-\eta} > (1-z)(1+\rho(1-\delta))$ . As the LHS is larger than one and the RHS is smaller than one,

$$\begin{aligned} (1-z)(1+\rho(1-\delta)) &= (1-z) \left( 1 + \frac{z}{1+n} \right) < 1 \\ \Leftrightarrow (1-z)(1+n+z) &< 1+n \\ \Leftrightarrow -z(n+z) &< 0. \end{aligned}$$

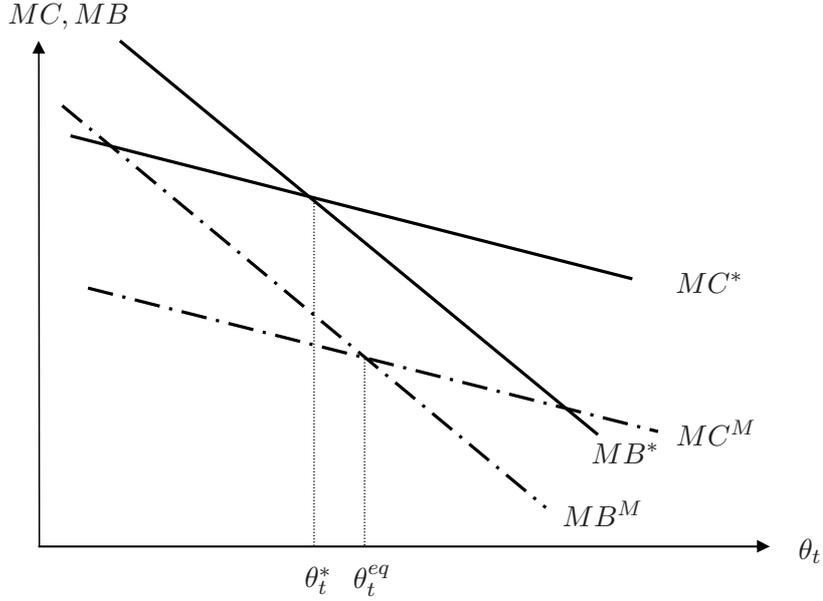


Figure 3: Comparison of  $\theta_t^{eq}$  and  $\theta_t^*$  for  $\alpha_t^{eq} = 1$ .

this condition is always satisfied, implying  $\theta_t^* > \theta_t^{eq}$ .

### A.3.2 $y_t^M \geq \tilde{y}_t$

Consider equation (36) and (37). Compared to the social planner, the median voter underestimates both the marginal costs (MC) and the marginal benefits (MB) of higher ecotaxes. Figure 3 illustrates. Specifically, the MC and MB for the social planner (indicated by a superscript \*) and the median voter (indicated by a superscript  $M$ ) are given by:

$$MC^* \equiv D(\theta_t) > d(\theta_t) \equiv MC^M$$

$$MB^* \equiv \frac{D(\theta_t)(1 - \varepsilon_{D,\theta})}{1 - \eta} - (2 + n)h'D'(\theta_t) \geq \frac{D(\theta_t)(1 - \varepsilon_{D,\theta})}{1 - \eta} \frac{y_t^M}{\tilde{y}_t} \frac{1}{1 + n} - h'D'(\theta_t) \equiv MB^M$$

Both MC and MB decrease in  $\theta_t$  and, additionally,  $\left| \frac{\partial MC}{\partial \theta_t} \right| < \left| \frac{\partial MB}{\partial \theta_t} \right|$  by the SOCs (equations (41) and (42)). That is, the (negative) slope of marginal benefits is steeper than for marginal costs which ensures a maximum.

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