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Public and private environmental spending: a political economy approach

Pierre-André Jouvet,[1] Philippe Michel, and Pierre Pestieau[2]
[1]Economix and CORE, [2]CORE, CREPP, PSE and CEPR, Université Paris X, UFR SEGMI, 200 Avenue de la République, 92001 Nanterre cedex, France

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Abstract This study examines the level of public investment in environmental quality when there are private alternatives. Public investment is chosen by majority voting. When consumption and environmental quality are complementary, one may observe a solution of the type "ends against the middle." The setting is intertemporal. Parents are altruistic and they can express their altruism by leaving financial bequests, but also by voting and contributing to the environmental quality their children will enjoy.

Key words Altruism · Voting · Public goods · Environmental policy

1 Introduction

Altruistic parents are concerned about the welfare of their descendants. In a world with only private goods and assuming operative bequests (Barro 1974) they have the possibility to control their offsprings' flow of consumption through financial and educational transfers. However, in a world with intergenerational public goods such as the environment, free riding makes it impossible to individually control the quality of environment their children can count on. Yet there are two indirect ways, one public and political and the other private and individual, to overcome this difficulty; namely, make sure that one's children benefit from a desirable environmental quality. In this article we look at a problem such as the quality of water that deteriorates at a constant rate and can be preserved collectively or privately. We adopt a dynamic model of successive generations. Bequest motive is the source of savings. In each generation, the quality of environment can be enhanced by public investment. The collective nature of such investment is particularly welcome because of the public good characteristic of the environment. This public investment is financed by a flat-rate income tax. Individuals differ in their labor productivity and in their initial endowment. Hence, this public environmental policy can be viewed as progressive. Individuals, presumably those who can afford it, can also invest privately in environmen-

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Philippe Michel passed away on July 22, 2004.

tal quality; this investment does not have any externality. To pursue our example of water quality, public investment would be a collective purification plant and private spending would consist of individual water filters. Given the progressivity of the environmental policy, well-to-do households could prefer individual over collective techniques even though the latter is more cost efficient than the former. Henceforth, if the tax rates and thus the level of public investment are chosen by votes, one can expect that the most preferred tax rate decreases with income and eventually reaches zero.

This conjecture is not necessarily verified for low incomes. We assume that an individual's utility depends on consumption, environmental quality, and the utility of his children. If consumption and environment are strong complements, a poor individual can vote against a high tax rate that would lead to a low consumption level. Indeed we show that in case of complementarity between consumption and environmental quality, we can have a coalition of low-income and high-income individuals opposing middle-income individuals in the determination of the tax rate. This is what Epple and Romano (1996a) call "ends against the middle" and it is a case where the median voter theorem does not apply. To get this particular result, one needs not only complementarity between consumption and environment quality, but also the possibility of supplementing public provision by private purchases. We have here the two key features of our model: the possibility of private contribution and the substituability between consumption and environment.

There is not much work on the issue of voting for environmental quality. Recent work by Kempf and Rossignol (unpublished) showed that public spending tends to be larger in societies with less inequality. There is also an article by Aidt (1998) who analyzed environmental policy in a common agency model of politics. Competition between lobby groups keeps the economy away from the efficient Pigouvian rule. Also, McAusland (2003) looked at the issue of voting for pollution policy within an open economy setting. She showed that poorer voters may be the greener voters within the electorate for reasons close to those developed in our paper. Even though richer voters are in favor of higher environmental quality they may be unwilling to pay more. Finally, Jouvet et al. (2000) discussed, the issue of environmental quality in a dynamic setting with altruism but without any political economy feature.

In most work on intergenerational altruism, parental altruism expresses itself only through financial bequests. It would seem natural to expect that parents also want to improve the quality of the environment their children will enjoy. As we show in the concluding section, our model can be interpreted along this line at the cost of an assumption of stationarity. Under this alternative specification, altruistic parents can influence both the consumption and the environment of their children.

The remainder of this article is organized as follows. Section 2 presents the model. Section 3 focuses on the steady-state solution; it gives the optimality conditions and the laissez-faire solution. Section 4 gives the voting equilibrium and Section 5 concludes.

2 The model

At each period of time, N altruistic agents live and work for one period. There are I types of individuals. An agent of type i is characterized by his labor productivity α_i where $i = 1, \ldots, I$. In the economy there is a proportion p_i of agents of type i and we assume:

$$\sum_{i=1}^{I} p_i \alpha_i = 1 \tag{1}$$

Population is assumed to be constant. As usual in this literature, sex is assumed away. With constant population, each asexual individual has only one child.

2.1 Consumers

In period t, each agent of type i can improve his own environmental quality in a private way by an environmental expense e_{it}. The environmental quality for an agent is given by:

$$q_{it} = e_{it} + \Psi_t \tag{2}$$

where Ψ_t represents the contribution of public investment to the individual's environmental quality. We assume additivity of e and Ψ for the sake of simplicity.

Agent i's budget constraint is given by:

$$c_{it} = (1 - \tau_t)\alpha_i w_t + R_t x_{it-1} - e_{it} - x_{it} \tag{3}$$

where c_{it} is consumption, w_t is wage per unit of efficient labor, R_t is the return to capital investment. This agent receives a bequest x_{it-1} and gives x_{it} to his child; τ_t is the environmental tax.[1] Bequests are constrained to be nonnegative, $x_{it} \geq 0$.

An agent of type i, born in period t, derives utility from consumption c_{it}, environmental quality q_{it}, and his child's utility. Individual preferences for c and q are assumed to be homothetic and represented by a utility function $U(c_{it}, q_{it})$. $U(.)$ is an increasing, strictly concave, twice differentiable function and verifies Inada conditions. Thus, the marginal rate of substitution is defined by:

$$\frac{U_c(c,q)}{U_q(c,q)} = h\left(\frac{q}{c}\right) \tag{4}$$

where $h(.)$ is an increasing bijection on $\Re_{++}$.

At period t, the welfare of an agent of type i, V_{it}, is defined by:

$$V_{it} = U(c_{it}, q_{it}) + \gamma V_{it+1} \tag{5}$$

[1] Admittedly this is a simplistic way of collecting revenue. It is, however, necessary to deal with the political economy model studied below.

where γ is a factor of altruism, $\gamma \in (0, 1)$. Agent i solves the following problem:

$$\begin{cases} \max_{c_{it}, q_{it}, x_{it}, e_{it}} \sum_{t=0}^{\infty} \gamma^t U(c_{it}, q_{it}) \\ \quad \text{s.t.} \quad c_{it} = (1-\tau_t)\alpha_i w_t + R_t x_{it-1} - e_{it} - x_{it}, \\ \qquad\qquad q_{it} = e_{it} + \Psi_t, \\ \qquad\qquad x_{it} \geq 0, e_{it} \geq 0. \end{cases}$$

2.2 Government

The public side of environmental quality Ψ_t depends on total public spending, E_t: $\Psi_t = \Psi(E_t)$. Function Ψ is concave and twice differentiable: $\Psi' > 0$, $\Psi'' < 0$ with $\Psi(0) = 0$, $\Psi'(0) = \infty$ and $\Psi'(\infty) = 0$. The specification of Ψ is crucial. For simplicity, the marginal return to private spending is constant and equal to 1.[2] Whatever the number of agents might be, the marginal return of public spending decreases from $+\infty$ to 0. The properties we are concerned with are that when public spending is very large, its marginal return tends to be lower than that of a low level of private spending. These properties imply that on pure efficiency grounds (identical individuals), public investment should prevail up to the point where its marginal return (Ψ') equals unity (the return of the private technology). Because of its public good nature, public investment offers another advantage: it is more attractive than private investment up to the point where its marginal return times N ($N\Psi'$) equals 1.

As an illustration, take $\Psi(E) = AE^{\varepsilon}$ where $\varepsilon < 1$ and $A > 0$ is a scale factor. In the identical individuals case, environmental quality is given by

$$q = e + AE^{\varepsilon}$$

subject to $e + E/N$ being a constant. It is thus clear that $e = 0$ as long as

$$E \leq (\varepsilon NA)^{\frac{1}{1-\varepsilon}}$$

In what follows, we assume that in the first-best case wherein individuals are made identical the optimal E denoted E^* is below that upper bound. In the second best with heterogenous individuals, this condition does not hold anymore.

The environmental tax, τ_t, is used to finance E_t, that is, public environmental spending. The government's revenue constraint is given by

$$E_t = \sum_{i=1}^{I} p_i N \alpha_i \tau_t w_t = \tau_t N w_t \tag{6}$$

There is thus simultaneity between τ and E. In the final section, we introduce an alternative specification wherein a tax paid in t contributes to the environmental quality in $t + 1$.

2 Allowing for concavity would not change our results, but it would make the analytics more complicated.

2.3 *Behavior of firms*

At each period t, competitive firms produce an homogeneous good Y_t with capital K_t and labor L_t. We assume a well-behaved production function (increasing, concave, and homogeneous of degree one),

$$Y_t = F(K_t, L_t)$$

With total depreciation of capital after one period,[3] a representative firm, in period t, maximizes its profits π_t,

$$\pi_t = F(K_t, L_t) - w_t L_t - R_t K_t$$

With perfect competition, factor price w_t and R_t are given and are equal to their marginal productivities,

$$F_L(K_t, L_t) = w_t, \tag{7}$$

$$F_K(K_t, L_t) = R_t. \tag{8}$$

2.4 *Equilibrium for a given policy*

The equilibrium conditions for an agent i are given by the following first-order conditions:

$$-U_c(c_{it}, q_{it}) + U_q(c_{it}, q_{it}) \leq 0; = 0 \quad \text{if} \quad e_{it} > 0 \tag{9}$$

and

$$-U_c(c_{it}, q_{it}) + \gamma R_{t+1} U_c(c_{it+1}, q_{it+1}) \leq 0; = 0 \quad \text{if} \quad x_{it} > 0. \tag{10}$$

The intertemporal equilibrium is defined for a given sequence of government decisions τ_t, by a sequence of prices w_t and R_t, and individual variables satisfying all the equilibrium conditions. The government's decision satisfies its budget constraint of Eq. 6. Consumers' decisions maximize their utility in Eq. 5, which yields Eqs. 9 and 10. Firms decisions imply Eqs. 7 and 8.

The capital stock is equal to the sum of bequests,

$$K_{t+1} = \sum_i p_i N x_{it} = N\bar{x}_t \tag{11}$$

where $\bar{x}_t$ is the average value of bequests. The return to bequest is given by the marginal productivity of capital Eq. 8. The markets of labor and goods are cleared such that we respectively have:

$$L_t = \sum_i p_i \alpha_i N = N \tag{12}$$

[3] Or equivalently that $F(K, L)$ includes capital after depreciation.

and

$$Y_t = N\overline{c}_t + N\overline{e}_t + E_t + N\overline{x}_t \tag{13}$$

where $\overline{c}_t = \Sigma_i p_i c_{it}$, $\overline{E}_t = \Sigma_i p_i e_{it}$.

The initial conditions $x_{i,-1} \geq 0$ for all $i = 1, \ldots, I$ are given with $\Sigma_i p_i N x_{i,-1} = K_0 > 0$.

3 Equilibrium and optimum in the steady state

With a constant tax rate $\tau_t = \tau$, the steady state satisfies $E = \tau N w$, $L_t = N$, $K_{t+1} = K$, $k = K/N = \Sigma_i p_i x_i = \overline{x}$, $e_{it} = e_i$, $x_{it} = x_i$, $c_{it} = c_i = (1 - \tau)\alpha_i w + (R - 1)x_i - e_i$, and $q_{it} = q_i = e_i + \Psi(E)$. A positive stock of capital implies that at least one bequest x_i is strictly positive and therefore from Eq. 10, we obtain the modified golden rule,

$$F_K\left(\hat{k}, 1\right) = \frac{1}{\gamma} \tag{14}$$

with $k = \hat{k}$ being the stationary stock of capital. Then at the steady-state equilibrium $R = \hat{R} = 1/\gamma$, and $w = \hat{w} = F_L(\hat{k}, 1)$. Type i's individuals have a life-cycle income:

$$\omega_i = (1 - \tau)\alpha_i \hat{w} + \left(\hat{R} - 1\right)x_i. \tag{15}$$

In the long run, wealth distribution depends on $x_{i,-1}$ and on the dynamics. When there is no constraint on bequest, each altruistic agent has the same behavior as an infinitely lived agent facing the following intertemporal budget constraint,

$$\sum_{t=0}^{\infty} \rho_t (c_{it} + e_{it}) = x_{i,-1} + \sum_{t=0}^{\infty} \alpha_i \rho_t w_t (1 - \tau) \equiv \Omega_i \tag{16}$$

where $\rho_t = \rho_{t-1}/R_t$, with $\rho_0 = 1$, are the discount factors. Then the long run net wealth distribution depends on the distribution of Ω_i and on the $x_{i,-1}$. When the ranking of $x_{i,-1}$ is the same as that of α_i, the distribution of net wealth is the same as the distribution of labor productivities α_i. In order to simplify our study, we assume that, at the stationary equilibrium, bequests are proportional to labor productivities, that is, $x_i = \alpha_i \overline{x} = \alpha_i \hat{k}$.

3.1 *Laissez-faire* ($E = 0$, $\tau = 0$)

Each agent i maximizes his utility subject to his budget constraint with $\tau = 0$, that is, *max* $U(c_i, e_i)$ subject to $c_i + e_i = \omega_i = \alpha_i \hat{w} + (\hat{R} - 1)\alpha_i \hat{k}$. Then Eq. 9 implies

$$U_c(c_i, e_i) = U_q(c_i, e_i) \tag{17}$$

which is equivalent to $e_i/c_i = h^{-1}(1) \cong \mu$. Therefore, with the assumption of homothetic preferences we obtain that private environmental spending is proportional to consumption, $e_i = \mu c_i$ and to the net income, ω_i, (and also to α_i). Clearly the homotheticity assumption is not innocuous.

3.2 Social optimum and the decentralization

In a centralized economy, all agents have the same consumption, $c_i = c$ and $e_i = e$ after redistribution. The environmental quality is defined by $q = e + \psi(E)$. The central planer maximizes $U(c, e + \psi(E))$ with respect to c, e, and E subject to $c + e + E/N = f(\hat{k}) - \hat{k}$, $c \geq 0$, $e \geq 0$, and $E \geq 0$.

The solution with $e^* = 0$ satisfies

$$U_c(c^*, \psi(E^*)) = B\psi'(E^*)U_q(c^*, \psi(E^*)) \tag{18}$$

The condition for $e^* = 0$ is equivalent to $\psi'(E^*) \geq 1/N$: at the steady state, the productivity of public spending is larger than that of private spending.

Contrasting Eq. 17 and Eq. 18 is interesting. In a laissez-faire setting, given our assumption on preferences, each individual contributes to the quality of the environment: e_i has to be positive and is financed privately. In the first-best optimum, we expect that $E^* > 0$ and $e^* = 0$. This mainly depends on $\Psi(E)$ and on N. But this is just an assumption. Nothing precludes Ψ to be so inefficient and N to be so low that even in the first-best optimum, private contribution would be the best device to maintain environmental quality.

We now move to a positive setting and try to assess the level of private contributions for a given value of τ and thus of $E = \tau N\hat{w}$.

3.3 Private environmental contribution for a given public policy

Case $e_i > 0$. If $e_i > 0$ then Eq. 9 implies

$$U_c(c_i, q_i) = U_q(c_i, q_i), \tag{19}$$

which is equivalent to $q_i/c_i = h^{-1}(1) \equiv \mu$. The budget constraint is

$$c_i + e_i = (1-\tau)\alpha_i\hat{w} + \left(\hat{R}-1\right)\alpha_i\hat{k} \equiv \omega_i \tag{20}$$

and with $\mu c_i = q_i = e_i + \Psi(E)$ we obtain

$$e_i\left(1+\frac{1}{\mu}\right) = \omega_i - \frac{\Psi(E)}{\mu}. \tag{21}$$

Hence, $e_i > 0$ if and only if $\omega_i > \Psi(E)/\mu$. This condition is equivalent to $h(\Psi(E)/\omega_i) < h(\mu) = 1$ and thus $e_i > 0$ if and only if $U_c(\omega_i, \Psi(E)) < U_q(\omega_i, \Psi(E))$. An agent chooses a positive environmental contribution, $e_i > 0$, if the consumption of his net income ω_i induces a lower marginal benefit of consumption than the environmental quality financed by the government.

Case $e_i = 0$. If $e_i = 0$, then $U_c(c_i, q_i) \geq U_q(c_i, q_i)$ with $q_i = \Psi(E)$ and $c_i = \omega_i$. The condition for $e_i = 0$ is $U_c(\omega_i, \Psi(E)) \geq U_q(\omega_i, \Psi(E))$.

The two cases can be presented in the following way,

$$e_i = \max\{0, \mu c_i - \Psi(E)\} \tag{22}$$

and the corresponding stationary welfare $V_i(E)$ satisfies

$$V_i(E) = \sum_0^{\infty} \gamma^t U(c_i, q_i) = \frac{1}{1-\gamma} U(c_i, q_i) \tag{23}$$

We now turn to the central section of this article: the determination of τ or E through majority voting. We first have to characterize the individual's indirect utility with E or τ as arguments.

4 Voting equilibrium

We now show that the welfare function of an agent of type i, $V_i(E)$ is single-peaked and we study the variations of his preferred public spending level with respect to his productivity parameter αi. We then turn to the outcome of the vote.

4.1 Study of the welfare function

We introduce two life-cycle utility functions for the constrained case and for the unconstrained one.

Given by Eq. 15 and $\tau \hat{w} = E/N$, we write the income net of bequest of agent of type i as the following function of E,

$$\omega_i = (1-\tau)\alpha_i \hat{w} + \left(\hat{R}-1\right)\alpha_i \hat{k} = \alpha_i \hat{\omega} - \alpha_i E/N \equiv \omega_i(E) \tag{24}$$

where $\hat{\omega} = \hat{w} + (\hat{R} - 1)\hat{k}$. We denote

$$U_i^0(E) = U(\omega_i(E), \Psi(E)) \tag{25}$$

as the life-cycle utility when consumption is equal to $\omega_i(E)$ and thus the environmental quality is $\Psi(E)$.

We show in the Appendix that the strictly concave function $U_i^0(E)$ reaches its maximum at some point E_i^0 in the interval $(0, N\hat{\omega})$.

The "unconstrained" life-cycle utility is defined by choosing e_i, positive or negative, which maximizes

$$U(\omega_i(E) - e_i, \Psi(E) + e_i) \tag{26}$$

This maximum is reached when the partial derivatives U_c' and U_q' are equal and this is equivalent to $q_i = \Psi(E) + e_i = \mu c_i = \mu(\omega_i(E) - e_i)$. Thus, the maximum of Eq. 26 is

$$U_i^1(E) = U\left(c_i^1(E), \mu c_i^1(E)\right) \tag{27}$$

where $c_i^1(E) = \frac{1}{1+\mu}(\omega_i(E) + \Psi(E))$. The strictly concave function $U_i^1(E)$ reaches its maximum at E_i^1, the solution of $\Psi'(E_i^1) = \alpha_i/N$.

From Eq. 21, the constraint $e_i \geq 0$ is binding if and only if $E \geq \bar{E}_i$, where $\bar{E}_i$ is the solution of $\Psi(\bar{E}_i) - \mu\omega_i(\bar{E}_i) = 0$. Thus, we have

$$V_i(E) = \begin{cases} \dfrac{1}{1-\gamma} U_i^0(E) & \text{if} \quad E_i \geq \bar{E}_i \\ \dfrac{1}{1-\gamma} U_i^1(E) & \text{if} \quad E_i \leq \bar{E}_i \end{cases}$$

In the Appendix, we prove the following proposition:

Proposition 1. *The function $V_i(E)$ is single-peaked and it reaches its maximum either at E_i^1 if $E_i^1 \leq \bar{E}_i$ or at E_i^0 if $E_i^1 > \bar{E}_i$. In the latter case, E_i^0 belongs to the interval $(\bar{E}_i, E_i^1)$.*

It may help the intuition to depict graphically the problem at hand. Figure 1 presents the indirect utilities U_i^0 and U_i^1 for the two cases. For $E_i < \bar{E}_i$, U_i^0 prevails and for $E_i > \bar{E}_i$, U_i^1 prevails. The relevant indirect utility is given by the thick single-peaked curve.

From these two figures, we obtained the most preferred value of E for an individual of type α_i.

4.2 Variations of the preferred public spending level

For an agent of type i, the unconstrained preferred public spending $E_i^1 = E^1(\alpha_i)$ is the solution of $\Psi'(E_i^1) = \alpha_i/N$. This level is feasible (with $e_i \geq 0$) if and only if $E^1(\alpha_i) \leq \bar{E}_i$, where $\bar{E}_i$ is the solution of $\Psi(\bar{E}_i) - \mu\omega_i(\bar{E}_i) = 0$. These conditions:

$$E^1(\alpha_i) \leq \bar{E}_i$$

and

$$\frac{\bar{E}_i}{N} + \frac{\Psi(\bar{E}_i)}{\mu\alpha_i} = \hat{\omega}$$

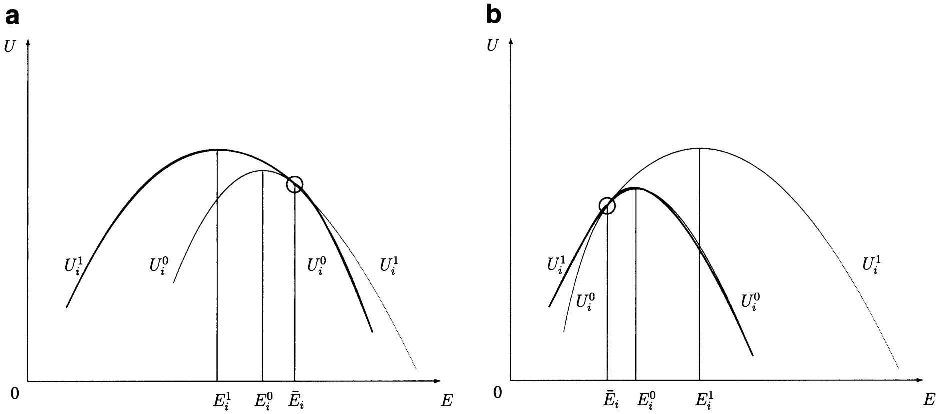

Fig. 1a,b. The relevant indirect utility. **a** The case $E_i^1 < \bar{E}_i$ ($e_i > 0$). **b** The case $E_i^1 > \bar{E}_i$ ($e_i = 0$)

are equivalent to

$$g(\alpha_i) = \frac{E^1(\alpha_i)}{N} + \frac{\Psi(E^1(\alpha_i))}{\mu\alpha_i} \leq \hat{\omega} \tag{28}$$

Because $E^1(\alpha) = \Psi'^{-1}(\alpha/N)$ is a decreasing function of α, $g(\alpha)$ is decreasing and the agents of type i reach their unconstrained preferred level $E^1(\alpha_i)$ if and only if $\alpha_i \geq \hat{\alpha}$, where $\hat{\alpha}$ is the solution of $g(\hat{\alpha}) = \hat{\omega}$. For these agents, $E^1(\alpha_i)$ is a decreasing function of the productivity parameter α_i.

If an agent of type i is constrained, that is, $\alpha_i < \hat{\alpha}$, his preferred level of public spending is $E_i^0 = E^0(\alpha_i)$, which is the solution of Eq. 33 in the Appendix:

$$\phi(E_i^0, \alpha_i) \equiv \Psi'(E_i^0) - \frac{\alpha_i}{N} h\left(\frac{\Psi(E_i^0)}{\alpha_i(\hat{\omega} - E_i^0/N)}\right) = 0$$

The function $\phi(E_i^0, \alpha_i)$ is decreasing with respect to E_i^0 (Ψ' is decreasing and h is increasing), and its derivative with respect to α_i is equal to

$$\frac{\partial\phi(E_i^0, \alpha_i)}{\partial\alpha_i} = \frac{1}{N}\left(z_i^0 h'(z_i^0) - h(z_i^0)\right) \tag{29}$$

where $z_i^0 = \dfrac{\Psi(E_i^0)}{\alpha_i(\hat{\omega} - E_i^0/N)}$ is the ratio of environmental quality to consumption. This can be summarized by the following proposition:

Proposition 2. If $\alpha_i \geq \hat{\alpha}$, *the preferred public spending level of the agents of type i is* $E^1(\alpha_i)$, *which is a decreasing function of the productivity parameter* α_i. *For* $\alpha_i \leq \hat{\alpha}$, *the preferred public spending level of the agents of type i is* $E^0(\alpha_i)$ *and the derivative of* $E^0(\alpha_i)$ *has the same sign as the elasticity of h at* z_i^0 *minus 1, where* $z_i^0 = \dfrac{\Psi(E^0(\alpha_i))}{\alpha_i(\hat{\omega} - E^0(\alpha_i)/N)}$.

4.3 The political equilibrium

Only if the preferred public spending level is a monotonic function of the productivity, the median voter theorem applies. This is the case when the elasticity of the function h is smaller or equal to 1: the two functions $E^0(\alpha)$ and $E^1(\alpha)$ are nonincreasing.

Proposition 3. *If the elasticity of h is smaller or equal to 1, then the preferred public spending level (and the corresponding tax rate) is nonincreasing with respect to the productivity parameter. Thus, the political equilibrium is the level preferred by the median voter (see Fig. 2a).*

When the elasticity of h is not smaller or equal to 1, the analysis of the vote is considerably more complex. In order to obtain explicit results, we now consider a constant elasticity of substitution (CES) utility function,

$$U(c, q) = \frac{1}{1 - 1/\sigma}\left(c^{1-1/\sigma} + \beta q^{1-1/\sigma}\right) \tag{30}$$

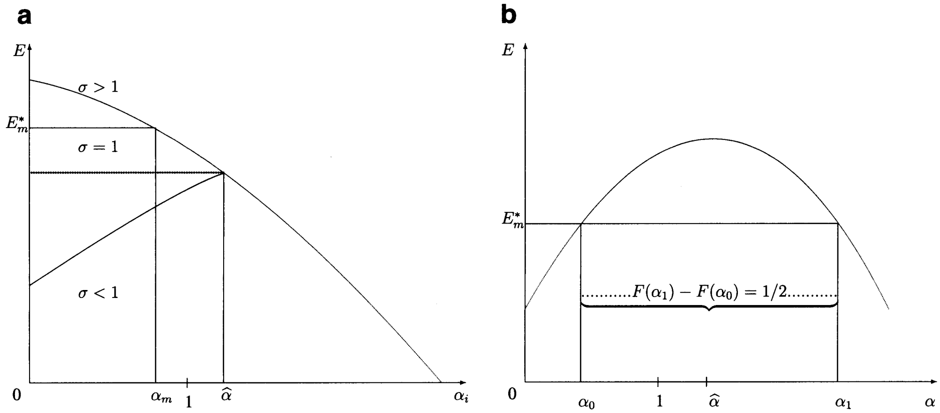

Fig. 2a,b. Ends against the mean. **a** Elasticity of substitution and the preferred public spending. **b** Ends against the middle

where σ is the elasticity of substitution and β is the environmental preferences parameter, $\beta > 0$. With this function, we have

$$h\left(\frac{q}{c}\right) = \frac{c^{-1/\sigma}}{\beta q^{-1/\sigma}} = \frac{1}{\beta}\left(\frac{q}{c}\right)^{1/\sigma} \tag{31}$$

The function h has the constant elasticity $1/\sigma$. Then, if $\sigma > 1$, the preferred public spending level $E^0(\alpha_i)$ is decreasing with α_i, but it is increasing if $\sigma < 1$.

Therefore, if we now consider a vote on the environmental tax τ, we have to distinguish the following possibilities:

If $\sigma > 1$, the preferred public spending is a decreasing function of α_i. Then, given the single peakedness of preferences, the median voter theorem applies. The individual of type α_m (median productivity) is therefore decisive.

If $\sigma = 1$, E_i^0 is constant, the median voter theorem applies as well, and under the assumption $\alpha_m \le \hat{\alpha}$ there is a majority vote in favor of E_i^0.

If $\sigma < 1$, E_i^0 is an increasing function of α_i. Then the median voter theorem does not apply and we have to use the Epple–Romano approach. That is, the voting equilibrium involves the worker with middle productivity individuals voting against a coalition of the lower productivity and the higher productivity individuals.

We know that if $\alpha_i > \hat{\alpha}$, the desired level of environmental quality decreases with α_i. For $\alpha_i < \hat{\alpha}$, any profile can be observed. Using a CES utility, we know that it decreases also with α_i if $\sigma > 1$ and then the Condorcet winner is the median productivity α_m worker. If $\sigma < 1$, we have the “ends against the middle” solution. In Fig. 2b, there is a coalition of workers with $\alpha_i < \alpha_0$ and $\alpha_i > \alpha_1$ against workers with $\alpha_0 < \alpha_i < \alpha_1$.

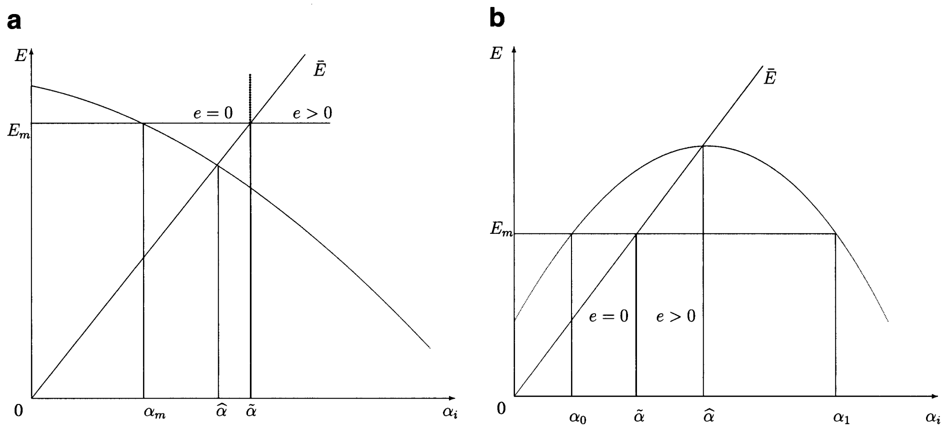

Fig. 3a,b. Rich against poor. **a** Median productivity and private contribution. **b** Contribution to environmental quality

The intuition is very close to that of Epple and Romano (1996b) or Casamatta et al. (2000). With complementarity, low-ability workers are not going to vote for a high tax because their consumption is closely related to the net of tax wage: $\alpha_\omega (1 - \tau)$. With substituability between c and q, they instead vote for a high rate of taxation realizing that so doing they will get a lot $\Psi(E)$ while paying little $(\tau\alpha\omega_i)$.

In Fig. 2, for the sake of intuition, we assume that the median wage $\omega_m < \bar{\omega} = 1$, which is standard, and that $\hat{\alpha} > 1$, which is less standard, and implies that only the richer workers privately contribute to the quality of their environment. Comparing Figs. 2a and 2b, we also see that the level of public investment tends to be lower in the case when the ends meet the middle.

We now look at the amount of private contributions that result from majority voting. We know that $\bar{E}_i$, the value of public spending, which makes workers of type i indifferent between contributing and not contributing, increases with α_i. Let us denote $\tilde{\alpha}$ as the productivity for which $\bar{E}_i$ and the majority choice of E are equal. As Fig. 3 indicates, all individuals with productivity above $\tilde{\alpha}$ will contribute to environmental quality improvement. We note that $\bar{E}$ intersects the curve with the most preferred E at $\tilde{\alpha}$. Not surprisingly, there will be more private contribution where ends meet the middle than when the median voter is decisive.

5 Conclusions

We have considered the case where environmental quality can be maintained by either public investment or private contribution. Public investment is financed by a flat-rate tax, which implies that workers with income below the average benefit from it. There is another reason why one could prefer public investment, namely technology. Given the public good nature of environmental quality and our assumption on technology, public investment is more cost efficient than private investment. This question is dealt within a growth model of successive generations where the motive for saving is parental altruism toward children. As a consequence, the modified golden rule is achieved in the long run and this drives some of the results. We are interested in the political economy choice of public investment by individuals of different productivity. We show that preferences are single-peaked in that in some case one readily applies the median voter theorem and in other cases one has to use the so-called "ends meet the middle" approach.

One of the avenues of further research is to introduce the idea of bequeathing not only financial or human capital, but also environmental quality. To do so, we would introduce a lag in the way public investment affects the environmental quality, whereas there would not be any lag for private protection. Taking the example of water, public infrastructure investment takes time whereas domestic purification devices have an instantaneous effect. These differential lags make the analytics more difficult. Note that we could also allow for a choice between private contribution to public investment and going through the political process. Suppose that parents can help their children by contributing s_i to a public investment or by investing time and money in a political process such as the one described here. There would be an interesting arbitrage between the efficiency loss linked to the "tragedy of the commons" and the loss associated with a redistributive political process.

Another extension we are thinking of is to link environmental deterioration to production, which would take us away from the very convenient modified golden rule. In the model presented thus far parents do not influence—at least directly—the quality of the environment their children will experience. We could modify this specification by having the parents not only leaving some inheritance to their children, but also voting for and contributing to the quality of their environment. In doing so they would express their altruism in a wider way than generally modeled in traditional models.

By means of this new specification we obtain that $\tau_t \omega_t = E_{t+1}$. Given that members of generation t make a decision concerning generation $t + 1$, the only consistent approach is to assume that we are in the steady state and that given E^* all future generations would choose the same level E^*, which is thus a fixed point.

With this interpretation, parents can directly influence their children's welfare: by providing them with a financial endowment and by insuring them an optimal level of environment. All parents will pay a tax that is proportional to their earnings even though some of them, the more productive, have voted against it. Those parents would, if they could, opt out of the public environmental policy and provide enough resources to their children for them to purchase private protection.

To conclude, we acknowledge that our view of environmental matters may appear simplistic. Our intention in this study was not to provide another model of environmental policy, but to cope with a neglected question that involves environmental policy: how can altruistic parents control the welfare of their offspring when this welfare depends not only on private consumption, but also on the quality of environment?

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Appendix

The maximum of $U_i^0(E) = U(\omega_i(E), \Psi(E))$

The function $U_i^0(E)$ is defined and strictly concave on the interval $(0, N\hat{\omega})$, because $U(c, q)$ is increasing and strictly concave, and $\omega_i(E) = \alpha_i(\hat{\omega} - \bar{E}/N)$ and $\Psi(E)$ are concave. Its derivative

$$\frac{dU_i^0(E)}{dE} = -\frac{\alpha_i}{N}U_c' + \Psi'(E)U_q' \tag{32}$$

tends to $+\infty$ (respectively to $-\infty$) when E tends to 0 (respectively to $N\hat{\omega}$). Thus, $U_i^0(E)$ reaches its maximum at E_i^0 where its derivative is equal to 0. Using $U_c'/U_q' = h(q/c)$ we obtain

$$\Psi'\left(E_i^0\right) - \frac{\alpha_i}{N}h\left(\frac{\Psi\left(E_i^0\right)}{\alpha_i\hat{\omega} - \alpha_i E_i^0/N}\right) = 0 \tag{33}$$

Proof of Proposition 1

1. The function $U_i^0(E)$ is decreasing for E such that $E \geq \bar{E}_i$ and $E \geq E_i^1$. Consider $E \geq \bar{E}_i$. Then the constraint $e_i \geq 0$ is binding and at $c_i = \omega_i(E)$ and $q_i = \Psi(E)$, we have $U_c' \geq U_q'$ and

$$\frac{dU_i^0(E)}{dE} \leq \left(-\frac{\alpha_i}{N} + \Psi'(E)\right)U_q' \tag{34}$$

The LHS is negative if $\Psi'(E) < \alpha_i/N$, that is, if $E > E_i^1$. Thus, $U_i^0(E)$ is decreasing for E such that $E \geq \bar{E}_i$ and $E \geq E_i^1$.

2. If $E_i^1 \leq \bar{E}_i$, the maximum of $U_i^1(E)$ is reached at E_i^1 with $e_i \geq 0$ and $U_i^0(E)$ is decreasing for $E \geq \bar{E}_i$. Thus, the maximum of $V_i(E)$ is reached at E_i^1 and $V_i(E)$ is single-peaked.
3. If $E_i^1 > \bar{E}_i$, then $U_i^1(E)$ is increasing for $E \leq \bar{E}_i$, and for $E \geq E_i^1$ $U_i^0(E)$ is decreasing. Thus, the maximum of $V_i(E)$ is reached at E_i^0, which belongs to the interval $(\bar{E}_i, E_i^1)$ and $V_i(E)$ is single-peaked.