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Short-lived agents and the long-lived environment

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Abstract

Actions that affect environmental quality both influence and respond to macroeconomic variables. Furthermore, many environmental and macroeconomic consequences of current actions will have uncompensated effects that outlive the actors. This paper presents an overlapping-generations model of environmental externalities and capital accumulation. Policies pursued by short-lived governments that affect capital accumulation and environmental quality, although myopically optimal, fail to internalize the long-lived external effects of their constituents' actions. Consequently, tax policies must be set by a long-lived government agency whose planning horizon is the environment's, not the individual agent's, lifetime.

Keywords: Environmental externalities; Overlapping generations; Capital accumulation

JEL classification: D62; D90; O41; Q29

1. Introduction

The 1992 United Nations Conference on Environment and Development (the 'Earth Summit') focused attention on the world environment and the economic and environmental effects of current behavior on future generations. Standard economic analysis suggests that if environmental problems

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can be classified as consumption and production externalities, their solutions are straightforward: either impose Pigouvian taxes or open markets in the externalities. Such analysis, being implicitly static, ignores two important aspects of the environmental problems central to the Earth Summit discussions. First, consumption and production externalities are inter- as well as intragenerational: actions taken today affect the welfare of future generations. Such external effects are intrinsically hard to internalize; their existence almost surely alters the set of socially desirable policies. Second, the macroeconomic perspective is missing. Actions that affect the environment both influence and respond to macroeconomic variables, and environmental policy decisions have implications for economic growth and capital accumulation. This paper considers how governments make decisions concerning the provision of a public good—environmental quality—where these decisions have long-lasting effects.

Environmental issues have been analyzed in the environmental and natural resource literatures (see Baumol and Oates, 1988; Conrad and Clark, 1987; Cropper and Oates, 1992; Dasgupta and Heal, 1979; and Neher, 1990). Researchers have investigated mechanisms under which a decentralized economy might successfully internalize environmental externalities. Such mechanisms include Pigouvian taxes (Wittman, 1985), markets for effluents (Krupnick et al., 1983), and pollution licenses (Montgomery, 1972). On the basis of these analyses, policies have been offered and in some cases successfully implemented (Hahn, 1989). But by assuming that the life span of individuals and the economy are the same, these researchers have restricted themselves to the analysis of *intragenerational* conflict. While our analysis also investigates policies that internalize the externalities present in the model, their design is complicated by our explicitly *intergenerational* focus.

Intergenerational issues have been discussed in the exhaustible resource literature (see Solow, 1974, 1986), but not, for the most part, in models of pollution. To date there is little use of an overlapping-generations framework in either the exhaustible resource or pollution literatures, despite the appeal of this structure for analysis of intergenerational issues. Exceptions are Kemp and Long (1980) and Mourmouras (1991) who construct overlapping-generations models of natural resources, and Sandler (1982) who analyzes the optimal provision of club goods in a finite-horizon economy.[1]

The model developed in this paper utilizes the overlapping-generations framework of Allais (1947), Samuelson (1958), and Diamond (1965). In the model agents live two periods, working while young and consuming while

[1] Howarth and Norgaard (1990) use a three-period model with distinct generations to consider the impact of property rights on intergenerational equity. Intergenerational externalities are the focus of John et al.'s (1993) analysis of weapons accumulation and arms control.

old. They divide their wage between saving and a tax used to maintain and improve the environment. Agents get utility from consumption and the quality of the environment; consumption degrades the environment left to future generations.

We analyze two cases. In the first the tax is determined by a one-period-lived government that sets taxes to maximize the utility of those alive during its term in office. The government ignores the effects of current consumption and taxation decisions on future generations' welfare. We find that economies better able to maintain their environments, with less polluting consumption or with slower population growth rates, enjoy better environments and higher capital stocks in steady-state equilibrium. These results suggest sources of environmental and economic differences between the East and the West, and the North and the South. Economies with more productive technologies or higher capital depreciation rates also enjoy better environments but their capital stocks may be higher or lower, in contrast to standard models.

We also analyze the decisions of a long-lived planner who maximizes the utility of a representative generation. The planner sets the capital stock to its golden rule level. In contrast, the steady-state equilibrium determined by a sequence of short-lived planners may be dynamically inefficient in either capital and/or the environment. In the dynamically inefficient economies Pareto-improving policies exist and can be achieved through tax-transfer schemes designed by the long-lived planner.

2. The environment

Consider an infinite-horizon economy comprised of two-period-lived agents, perfectly competitive firms, and a government that is either short- or long-lived. A new generation of N_t agents is born at each date $t = 1, 2, \ldots$. Population grows at the rate n: $N_t = (1+n)N_{t-1}$. Young agents have preferences defined over consumption in old age, c_{t+1}, and an index of the quality of the environment when they consume, E_{t+1}. These preferences are represented by $U(c_{t+1}) + \phi(E_{t+1})$. Assume that $U(\cdot)$ and $\phi(\cdot)$ are increasing, twice continuously differentiable, and strictly concave. Further assume $\lim_{c\to 0} U' = \infty$.

Since we focus on external effects across generations, we abstract from the well-understood free-rider problems within a generation. We assume, initially, that at the beginning of each date agents elect a government for a one-period term to enact policies for the benefit of agents alive during its term. The government levies lump-sum taxes on the young to achieve the desired environmental quality, a public good. In Section 5 we consider the taxes imposed by a long-lived government, set up to implement policies to improve the welfare of the current and all future generations. Such a government can design policies that internalize intergenerational externalities.

Young agents are each endowed with one unit of labor that they supply to firms inelastically. They divide their wage, w_t, between saving for old age consumption, s_t, and payment of an environmental maintenance and improvement tax, m_t. When old, agents supply their saving inelastically to firms and earn the gross return $(1 + r_{t+1} - \delta)$.

The quality of the environment is determined by

$$E_{t+1} = (1 - b)E_t - \beta N_{t-1}c_t + \gamma N_t m_t , \qquad (1)$$

where $b \in (0, 1]$ measures the autonomous evolution of environmental quality, $\beta N_{t-1}c_t$ is degradation of the environment by the consumption of the old at t, $\beta > 0$, $\gamma N_t m_t$ measures environmental improvement from government programs funded by tax revenues at t, $\gamma > 0$, and $E_1 \geq 0$ is given. $E_t \in \mathbb{R}$ is the index of environmental quality. One interpretation of E_t is the quality of soil or groundwater, where contamination reduces E_t and environmental clean-up increases E_t. Another interpretation of E_t might be the inverse of the stock of greenhouse gases in the atmosphere; maintenance in this case could correspond to the planting of trees. If we interpret environmental quality more broadly, we could also think of E_t as corresponding to national parks, which have amenity value and which also require maintenance.[2] In an economy undisturbed by human activity, $E = 0$; human actions either improve or worsen the environment.

Firms are perfectly competitive profit maximizers who produce using the constant returns production function $Y_t = \alpha F(K_t, N_t)$, $\alpha > 0$. Thus, output per worker can be written as $y_t = \alpha f(k_t)$, where k_t is the capital–labor ratio, and where $f'(\cdot) > 0$, $f''(\cdot) \leq 0$, $f(0) = 0$ and $\lim_{k \to \infty} f'(\cdot) = 0$. Assume that the capital stock depreciates at rate $\delta \in [0, 1]$ during the production process.

The representative agent at time t takes as given the wage, the return on saving, the tax, and the environmental quality, and chooses s_t and c_{t+1} to

$$\max U(c_{t+1}) + \phi(E_{t+1}) \qquad (2)$$

subject to

$$w_t = s_t + m_t , \qquad (3)$$

$$c_{t+1} = (1 + r_{t+1} - \delta)s_t , \qquad (4)$$

[2] For many environmental problems, such as biodiversity loss, ozone layer depletion, or air pollution, direct improvement of the environment is difficult or impossible. We could, however, interpret m_t as abatement measures to prevent environmental degradation, and view Eq. (1) as a linear approximation of a more complicated relationship between consumption, abatement, and environmental quality.

$$c_{t+1} \geq 0, \quad s_t \geq 0 .$$

The solution to this problem involves the agent setting saving equal to the after-tax wage and, when old, consuming the gross return on saving.

The individual firm takes wages and rental rates as given. It hires labor and capital until their marginal products equal their factor prices

$$\alpha[f(k_t) - k_t f'(k_t)] = w_t , \tag{5}$$

$$\alpha f'(k_t) = r_t . \tag{6}$$

The goods market clears when demand for goods equals supply of goods:

$$s_t + m_t + c_t/(1+n) = w_t + (1 + r_t - \delta)k_t . \tag{7}$$

Combining Eqs. (3), (4), and (7) yields

$$s_{t-1} = (1+n)k_t . \tag{8}$$

While individual agents do not internalize the effects of their actions on the quality of the environment, their elected officials do. The short-lived government imposes taxes on the young to maximize their lifetime utility subject to the conditions that the old cannot be made worse off by these actions, the firm sector is perfectly competitive, and the goods market clears. The government's problem is choose k_{t+1} to maximize (2) subject to (3)–(8), and (1), which reduces to

$$\max U[(1 + \alpha f'(k_{t+1}) - \delta)k_{t+1}(1+n)] \\ + \phi[(1-b)E_t - \beta N_{t-1}c_t + \gamma N_t(\alpha f(k_t) - \alpha k_t f'(k_t) - k_{t+1}(1+n))] .$$

The first-order condition is

$$U'(\cdot)(1 + \alpha f'(\cdot) - \delta + \alpha f''(\cdot)k_{t+1}) - \gamma N_t \phi'(\cdot) = 0 . \tag{9}$$

The government chooses k_{t+1} to equate the sum across agents of their marginal rates of substitution between consumption and environmental quality to the marginal rate of transformation.[3] Furthermore, (9) reflects the fact that the government recognizes that the return to capital is decreasing at the margin, and internalizes this effect when setting the maintenance tax.

The short-lived government's choices internalize the current period externality the young impose upon themselves when they are old by not

[3] Our analysis assumes an interior solution with $m > 0$, but nothing in the model precludes the possibility that the government chooses not to engage in any maintenance and sets $m = 0$. The zero-maintenance tax case is analyzed in a similar model in John and Pecchenino (1994). Note that the boundary conditions on the utility functions ensure that the government always chooses a strictly positive consumption level. In the absence of transfers to the old this is sufficient to guarantee that saving will be strictly positive.

taking account of the effects of their actions on environmental quality, a public good. Thus, the government's role reduces to the optimal provision of a public good for a single generation. The government does not, however, act in any way to affect the intergenerational externality imposed by the current generation on future generations via the bequeathed environmental quality.

3. The steady state

A competitive steady-state equilibrium for this economy is given by $\{c, m, e, k\}$, where $e \equiv E_t/N_t$, $\forall t$, such that

(i) the government maximizes (2) subject to (1) and (3)–(8) given δ and E_t;

(ii) per capita environmental quality is constant for all t:

$$e = \frac{\gamma}{n+b} m - \frac{\beta}{(n+b)(1+n)} c \,. \tag{10}$$

This definition of a steady state differs from the more standard case in which all generations enjoy equal utility. Here, environmental quality grows at rate n, so utility increases over time. The difference arises because environmental quality is a public rather than a private good. The standard concept of a steady state would hold E_t constant for all t, generating a decline in per capita environmental quality at rate n. A steady state in which all per capita values are constant exists only if the first-order condition is independent of N_t, that is if $\phi'(E_{t+1})$ is inversely proportional to N_{t+1}. Thus, in general, this model may not have a steady state. To permit a steady-state analysis, we assume that $\phi(E_t) = \ln E_t$, so that $\phi'(\cdot) = 1/(N_t e)$; this implies $E_t > 0$. For convenience we also assume $U(c_t) = \ln c_t$.[4]

With these functional forms, a steady-state equilibrium is represented by steady-state environmental quality

$$e = \frac{1}{n+b} [\gamma(\alpha f(\cdot) - \alpha k f'(\cdot) - k(1+n)) - \beta(1 + \alpha f'(\cdot) - \delta)k] \,, \tag{11}$$

and the first-order condition, (9),

[4] While the steady-state path is a special case, it allows for a direct comparison between this work and other Diamond-style overlapping-generations models without external effects (Diamond, 1965), and to standard static models with public goods. In a similar model without population growth (John and Pecchenino, 1994), out-of-steady-state behavior is analyzed. That model considers both positive and negative E.

$$\frac{[1+\alpha f'-\delta+\alpha f''(\cdot)k]}{[1+\alpha f'(\cdot)-\delta]k}-\frac{\gamma}{e}=0\,. \tag{12}$$

The short-lived government internalizes all intragenerational externalities, but intergenerational externalities remain. Deterioration of the environment due to consumption is a pure public bad. Improvement due to maintenance is not a pure public good because today's planner accounts for the effect of current maintenance on next period's environmental quality. The net external effect may be positive or negative. Because the externalities operate through changes in environmental quality, the autonomous evolution of the environment implies that the external effects of a given generation's actions die out over time. In the steady state, the marginal utility from environmental improvement also diminishes over time, because E_t is increasing.

4. Comparative statics

The comparative static results that follow are for an interior equilibrium. Total differentiation of Eqs. (11) and (12) yields:

$$\begin{bmatrix} 1 & \xi \\ \frac{\gamma}{e^2} & \zeta \end{bmatrix}\begin{bmatrix} de \\ dk \end{bmatrix} = \begin{bmatrix} \frac{m}{n+b} & \frac{-c/(1+n)}{n+b} & \frac{-e-\gamma k}{n+b} & \frac{\beta k}{n+b} & \frac{-(\beta+\gamma)f'k+\gamma f}{n+b} \\ \frac{1}{e} & 0 & 0 & \frac{-\alpha f''}{(1+\alpha f'-\delta)^2} & \frac{-f''(1-\delta)}{(1+\alpha f'-\delta)^2} \end{bmatrix} \times \begin{bmatrix} d\gamma \\ d\beta \\ dn \\ d\delta \\ d\alpha \end{bmatrix}, \tag{13}$$

where

$$\zeta \equiv -\frac{1}{k^2}+\frac{(1+\alpha f'-\delta)\alpha f'''-(\alpha f'')^2}{(1+\alpha f'\;-\delta)^2}$$

and

$$\xi \equiv \frac{1}{n+b}\left[(\gamma+\beta)\alpha f''k+\gamma(1+n)+\beta(1+\alpha f'-\delta)\right].$$

The determinant of the left-hand-side matrix is $\Delta \equiv \zeta - \gamma\xi/e^2$. The following conditions together are sufficient for $\Delta < 0$:
(i) $\zeta \leqslant 0$;
(ii) $\xi \geqslant 0$.
Sufficient for (i) is that consumption be a concave function of k, and sufficient for (ii) is that the maintenance tax $[\alpha f(k) - \alpha f'(\cdot)k - (1+n)k]$ be decreasing in k. Conditions (i) and (ii) are not very restrictive.

The following propositions set out the comparative static behavior of the model when preferences are logarithmic and conditions (i) and (ii) hold. Since the proofs are straightforward, they are left to the reader.

Proposition 1. Economies with better environmental maintenance technologies (higher γ) accumulate more capital and have higher environmental quality.

The representative government imposes taxes so that individual agents are indifferent between maintaining environmental quality and consuming. An economy with a more productive maintenance technology can devote less to maintenance to achieve a given environmental quality. Thus, both the environment and capital can be sustained at higher levels.

Proposition 2. Economies in which consumption causes greater environmental degradation (higher β) accumulate less capital and have poorer environments.

If each unit of consumption causes significant environmental degradation, then more resources must be dedicated to maintenance for the government to achieve the optimal allocation, leaving fewer resources for saving and consumption.

Propositions 1 and 2 identify two potential explanations for the divergent experiences of Eastern Europe and the OECD countries. Eastern Europe has experienced poor environmental quality and low levels of consumption. In our model, even if capital is equally productive in both East and West, the East could have suffered because it had access only to inferior environmental maintenance and/or disposal (consumption) technologies.

Proposition 3. Economies with higher population growth rates (higher n) have lower rates of capital accumulation and worse environmental quality.

An increase in the population growth rate increases the amount of stress placed on the environment, forcing a reallocation away from capital and consumption toward maintenance. The net effect of this is a reduction of both steady-state capital and environmental quality. This result is consistent with the divergence between the developed and the developing nations in both capital accumulation and environmental quality.

Proposition 4. Economies with higher rates of capital depreciation (higher δ) have higher equilibrium environmental quality and accumulate more or less capital than economies with lower rates of capital depreciation.

All else equal, the higher an economy's rate of capital depreciation, the lower its consumption and the better its environment. Whether the government reallocates resources from maintenance to capital accumulation depends on the marginal utility from a better environment relative to the marginal disutility from reduced consumption.

Proposition 5. More productive economies (higher α) have lower or higher equilibrium capital stocks and better environments.

Increases in productivity raise total output, allowing increased maintenance and consumption. These lead to a better environment and a higher or lower capital stock.

Propositions 4 and 5 differ from Solow (1956) in which higher rates of capital depreciation lead to lower rates of capital accumulation and better technologies lead to higher rates of capital accumulation. The differences arise because capital accumulation has two contradictory effects in this model: increased consumption, a good, and increased pollution, a bad.[5]

5. The policies of a long-lived government

Examination of the short-lived government's problem reveals that while *intragenerational* externalities are internalized, *intergenerational* ones are not. This is because the short-lived government's planning horizon is the same as the life span of an individual. A long-lived government making plans over the infinite lifetime of the environment can take both intra- and intergenerational effects into account. The feasibility of implementing these plans is open to question, because intergenerational externalities are

[5] The result in Proposition 4 that $dk/d\delta$ may exceed zero stems from the consumption externality. If it were replaced by a production externality, then $dk/d\delta < 0$, as in Solow, but results qualitatively equivalent to those stated in Propositions 1, 3, and 5 would continue to obtain. Not surprisingly, in a model with a production externality, an increase in the environmental degradation resulting from each unit of production leads to a lower steady-state capital stock and a higher or lower environmental quality. Here lower capital reduces output which reduces pollution, but may also lead to lower maintenance, hence the ambiguous effect on environmental quality.

intrinsically hard to internalize: those imposing the externalities are not alive at the same time as those who enjoy or suffer the consequences.

To compare the short- and long-lived governments' problems we restrict our attention to the infinitely-lived government's choice of a steady state, under the assumption of logarithmic utility. The long-lived government chooses the steady-state capital stock and maintenance tax to maximize the utility of a representative generation. That is, the planner solves

$$\max \ln c + \ln e \tag{14}$$

subject to (10) and

$$\alpha f(k) + (1-\delta)k = c/(1+n) + m + k(1+n)\,, \tag{15}$$

where (15) represents economic feasibility and (10) is steady-state environmental quality. The first-order conditions are

$$\alpha f'(\cdot) - (n+\delta) = 0\,, \tag{16}$$

$$\frac{-(1+n)}{c} + \frac{\gamma+\beta}{(n+b)e} = 0\,. \tag{17}$$

From (16), the government sets capital at the golden-rule level where net per capita output is maximized. From (17), the optimal maintenance tax internalizes consumption and maintenance externalities by recognizing the intergenerational effects, $(\gamma+\beta)/(n+b)$, which the short-lived planners ignore. That is, the long-lived government recognizes that consumption (maintenance) today degrades (improves) the environment bequeathed to the next generation, and so equates the social marginal rate of substitution between consumption and environmental quality to the marginal rate of transformation.

While the short-lived planner is constrained to dividing young agents' wages between saving and maintenance, the long-lived planner can divide net output between consumption by the old and taxes by the young to achieve a constant level of environmental quality. Thus the planner can translate an increase in output into increased consumption while keeping environmental quality constant, thus unambiguously increasing utility. The planner therefore chooses k to maximize output, and then divides it optimally.

The long-lived planner recognizes that the trade-off between capital and the environment perceived by the short-lived government is inefficient since it ignores the potential for intergenerational trades (the overlapping-generations effect) and the intergenerational environmental effects of consumption and maintenance. For the long-lived planner to achieve Pareto-improving reallocations in the absence of intergenerational altruism, the initial old must not be discomfited. Thus, Pareto-improving reallocations are possible if the decisions of short-lived governments lead to dynamically inefficient allocations: overaccumulation of capital and/or overaccumulation of environmental quality in a steady-state equilibrium.

Proposition 6. Call the steady-state solution to the short-lived planner's problem $(\hat{k}, \hat{e})$ and the solution to the long-lived planner's problem (k^*, e^*). If $\hat{k} > k^*$ and/or $\hat{e} > e^*$ at a feasible $\hat{k}$, then Pareto-improving policies exist.

Proof. If $\hat{k} > k^*$ a reduction in the steady-state capital stock at any date t increases output. Since this output can be allocated such that per capita environmental quality is maintained while consumption is increased, the reallocation is Pareto improving. Let $\hat{e} > e^*$. Consider a small reduction μ in the tax at all dates, holding k constant. This implies a transfer to the old of $\mu(1+n)$, which increases their consumption at all dates. From (10) the change in steady state e is $-(\gamma+\beta)\mu/(n+b)$. Taking a Taylor series expansion around steady-state consumption and environmental quality implies a change in utility of $\mu[(1+n)/\hat{c} - (\gamma+\beta)/(n+b)\hat{e}]$. Since (10) and (15) are satisfied in any steady state, it follows that $\hat{c} < c^*$, while $\hat{e} > e^*$. From (17) the change in utility is positive; the reallocation is Pareto improving. □

Recall that the short-lived planner internalizes the effect of capital accumulation on the return to capital. This is manifested in the $\alpha f''(\cdot)k$ term in (9). Since $f''(\cdot) < 0$, the internalization biases the planner's choice away from capital towards maintenance. It can be shown that the combination of $\hat{k} < k^*$ and $\hat{e} > e^*$ is only possible here because of this effect. That is, if the planner were a price-taker with respect to the interest rate or the interest rate were fixed, dynamically efficient capital accumulation and inefficient environmental quality could not coexist.[6]

When Pareto improvements are possible a long-lived planner can design a taxation scheme that leaves the tax choice to the short-lived government but which allows the economy to obtain the steady-state optimum.

Proposition 7. The long-lived planner can implement a tax-transfer scheme such that the short-lived planner's choice will achieve the social optimum.

Proof. Suppose the long-lived planner taxes the net return on capital and wages at the rates τ_k and τ_w, respectively. In the presence of such taxes, the short-lived government's problem is to

[6] John and Pecchenino (1994) establish this result in a similar model. They also show that $\hat{k} < k^*$ and $\hat{e} > e^*$ can arise if there are external increasing returns to capital.

$$\max \ln c_{t+1} + \ln E_{t+1}$$

subject to (1) and

$$m_t = [\alpha f(k_t) - \alpha k_t f'(k_t)](1-\tau_w) - k_{t+1}(1+n)\,,$$

$$c_{t+1} = [1 + \alpha f'(k_{t+1}) - \delta](1-\tau_k)k_{t+1}(1+n) + \sigma_t\,,$$

$$c_{t+1}, k_{t+1} \geqslant 0\,,$$

where σ_t is a per-capita transfer (lump-sum tax) to the old of generation t.

A steady-state equilibrium for this economy is the vector $\{c, m, k, t, e\}$ such that the short-lived planner optimizes, and the government budget constraint is satisfied:

$$N_{t+1}\tau_w[\alpha f(k) - \alpha k f'(k)] + N_t\tau_k[1 + \alpha f'(k) - \delta]k(1+n) = \Sigma_t$$

and

$$\sigma_t = \Sigma_t / N_t\,, \quad \forall t\,.$$

In the steady state the short-lived government's indirect social welfare, as a function of the wage and capital tax parameters, is

$$\begin{aligned} V(\tau_k, \tau_w) \equiv \ln[\{[1 + \alpha f'(\bar{k}) - \delta]\bar{k} + \alpha\tau_w[f(\bar{k}) - \bar{k}f'(\bar{k})]\}(1+n)] \\ + \ln\Big[\Big(\frac{N_{t+1}}{n+b}\Big)\{\gamma[[\alpha f(\bar{k}) - \alpha\bar{k}f'(\bar{k})](1-\tau_w) - \bar{k}(1+n)] \\ - \beta[[1 + \alpha f'(\bar{k}) - \delta]\bar{k} + \alpha\tau_w[f(\bar{k}) - \bar{k}f'(\bar{k})]]\}\Big]\,, \end{aligned}$$

where $\bar{k} = k(\tau_k, \tau_w)$ implicitly defines the capital stock in a steady-state equilibrium.

The long-lived planner chooses τ_k and τ_w to maximize the indirect social welfare function. The first-order conditions simplify to

$$\alpha f'(\bar{k}) = \delta + n,$$

$$\frac{1+n}{c} - \frac{\gamma + \beta}{e(n+b)} = 0,$$

where c and e are consumption and environmental quality, respectively, as functions of the tax rates. These conditions define τ_k and τ_w. The first-order conditions for the direct and indirect long-lived planner's problems are identical: the long-lived planner can choose tax parameters to induce the short-lived planner to the steady-state social optimum. □

The long-lived planner designs the *intertemporal* Pigouvian tax-transfer scheme so that short-lived agents receive the full benefit of their taxes on environmental quality, while bearing the total cost of their consumption. If the economy is dynamically efficient in both capital and environmental quality, a Pareto-improving tax-transfer scheme cannot exist. This result is similar to Weitzman's (1974) regarding the difficulty of implementing optimal Pigouvian taxes. In a static model Weitzman shows that those who benefit from the imposition of the taxes may not be those upon whom the taxes fall. To ensure that a tax-transfer scheme results in a Pareto improvement, transfers from the beneficiaries are required. In our model the same is true, except that those who benefit may not yet be alive, and so transfers may not be feasible.

6. Conclusion

Actions that affect environmental quality both influence and respond to macroeconomic variables, and many environmental and macroeconomic consequences of agents' actions have uncompensated effects that outlive the actors. This paper has examined the steady-state equilibrium behavior of an overlapping-generations model of environmental externalities and capital accumulation in which taxes to maintain and improve environmental quality are imposed on young agents, and where the consumption of the old degrades the environment. We find that while a short-lived government provides the myopically optimal level of capital and the public good, environmental quality, its policies fail to address the effects of today's choices on future generations. A long-lived planner can design policies to provide the dynamically optimal level of capital and the public good, but such policies may not be Pareto improving.

Our model argues for the recognition of intergenerational externalities in formulating environmental and macroeconomic policy. Specifically, the costs of any policy must be compared with the benefits for not only the current generation, but for all future generations as well. This suggests that the incorporation of public debt into this model, thus allowing a mechanism for borrowing from future generations, is a promising direction for future research. Our model also suggests that environmental policies, such as those proposed at the Earth Summit, are unlikely to be adopted in the absence of intergenerational altruism, and that intergenerational conflict may be at least as significant as international disagreement.[7]

[7] John and Pecchenino (1993) analyze both intergenerational and international environmental externalities.

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