The Intergenerational Political Economy of Natural Resources and Environmental Externalities

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Abstract

Our modern society has difficulties to implement public policies limiting long-term global environmental externalities such as climate change. While the international coordination issue is a well known reason for this policy failure, the intergenerational coordination issue is hardly evoked. The present paper tackles this issue by developping an overlapping generation model in which the use of an exhaustible natural resource generates a long-term global environmental externality. We show that an intertemporal global policy maker would implement a Pigouvian tax on the natural resource (welfare economics approach), but a democratic global policy maker would in general implement a tax below the Pigouvian level as the latter policy maker only represents the living generations (political economy approach). The analysis gives new insights on the Pigouvian tax formula, in particular the discounting factor. Moreover, it explains how the lack of coordination between the policy makers of different periods affects the tax level. The implementation of a tax close enough to the Pigouvian level requires either high individual altruism towards descendants or high voting power for young generations.

Keywords: Overlapping generations; Welfare economics; Political economy; Discounting; Altruism; Natural Resources; Fossil Fuels; Environmental Externalities; Climate Change.

JEL codes: D6; D7; O13; Q32; Q56.

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1 Introduction

One of the main challenges of our modern societies is to deal with the over-exploitation of exhaustible natural resources that generates long-term global environmental externalities. The most pressing issue is climate change, which is mainly due to the use of fossil fuels. Another main issue is biodiversity loss due to natural resource exploitation in general. Simple policies, such as a carbon tax for climate change, would lower these externalities and increase social welfare. Combined with transfer policies, they would even lead to Pareto-improvement. However, policy makers hardly implement these policies.

The lack of policy implementation for environmental externalities such as climate change finds its roots in the political system which determines political decisions. While a large part of the literature explains this lack by the international coordination issue[1], the present paper argues that intergenerational coordination is also a main issue which partly explains why environmental policies like a carbon tax are not implemented and even why fossil fuel subsidies might be implemented. We build an overlapping generation model in which the use of an exhaustible natural resource generates a long-term global environmental externality. We show that an intertemporal global policy maker would implement a Pigouvian tax on the natural resource (welfare economics approach), but a democratic global policy maker would in general implement a tax below the Pigouvian level as the latter policy maker only represents the living generations (political economy approach). In some cases, the democratic policy maker might even subsidize (instead of tax) the use of natural resource to give incentives to living individuals to over-exploit the resource in their benefits. This result can explain why fossil fuel subsidizations are currently in place in the real world despite climate change (Coady et al., 2019). Moreover, our results suggest that higher individual altruism towards descendants and higher voting power for young generations would lead to higher support to policies limiting long-term environmental externalities.

We develop an original and simple overlapping generation model with two periods and three generations, each one composed of a continuum of identical agents. Generation 1 is old and endowed with natural resource in the first period. Generation 2

[1] In a world with multiple countries and no global policy maker, the policy maker of each country has incentives to free-ride on others and thus not to implement environmental policies like a carbon tax. See for instance Batabyal (2017) for an overview of the literature on international environmental agreement.

is young and endowed with labour force in the first period, and becomes old in the second period. Generation 3 is young and endowed with labour force in the second period. Consumption goods are produced with natural resource and labour force. Natural resource is exhaustible (i.e. not renewable) and can be saved from the first to the second period. The use of natural resource in the first period generates an externality in the second period. Agents have standard utility functions. For generation 2's agents living two periods, the utility is time-additive with a pure time preference parameter. In addition, agents might be altruistic towards their direct descendant.[2] Our modeling disentangles individual pure time preference and individual altruism towards descendant, which are entangled in infinitely lived agent models (Barro, 1974; Schneider et al., 2012). Natural resource and consumption goods can be exchanged thanks to efficient markets within each period. A policy maker can implement a tax on the use of natural resource in the first period and lump-sum transfers between generations within each period.

We first consider the case of a policy maker similar to a benevolent social planner in the tradition of welfare economics. Such a policy maker aims at maximizing a social welfare function in which some weights are given to the agents of each generation. In the decentralized economy, we show that the policy instruments (tax on natural resource and lump-sum transfers) allow the policy maker to implement the Pareto optimal allocation corresponding to the chosen weights in the social welfare function. The tax corresponds to the Pigouvian tax with a discount rate over the marginal damage because of the delay of the impacts. The discount rate and thus the tax depend on the chosen weights in the social welfare function. The higher the weights for future generations, the lower the discount rate and the higher the tax, which is in line with the results of the discounting literature (Nordhaus, 2007). However, our discounting formula gives new insights on how the weights for future generations affect discounting. In the standard discounting formula obtained with infinitely lived agent models[3], individual pure time preference and weights given to different generations are entangled and directly affect the discount rate. In the present model in which they

[2]Following Galperti and Strulovici (2017), we consider pure altruism, in the sense that an agent A who is altruistic towards her direct descendant weights the total utility of her descendant B. This means that if her descendant B is altruistic towards her own descendant C, the agent A weights indirectly in her own utility the utility of agent C.

[3]The standard discounting formula obtained with infinitely lived agent models is the standard Ramsey equation (Cass, 1965; Koopmans et al., 1963; Ramsey, 1928).

are disentangled, weights given to different generations do not have a direct impact on the discount rate. Increasing the weight of future generations simply increases the consumption of young agents relative to old agents within a period and decreases the consumption growth over individual lifetime, which indirectly decreases the discount rate and increases the tax.

We then consider the more realistic case of a policy maker similar to one obtained in a political system with voting, such as a democracy. Following political economy modeling and more specifically the probabilistic voting model (Bierbrauer and Boyer, 2016; Lindbeck and Weibull, 1987), such a policy maker aims at maximizing a social welfare function in which the weight for each agent characterizes her voting power and sensitivity. In this case, the objective of the policy maker changes from one period to another since the voters are changing. Clearly, only living generations are weighted in the social welfare function considered by the policy maker of a given period. In the decentralized economy, we show that the policy maker will not implement a Pareto optimal allocation because of time inconsistency. The only exception is the case where the voting power of young agents is null, but in this case the consumption level of future generations fully relies on the altruism of current generations. In the general case, the policy maker of the first period will implement a tax on natural resource below the Pigouvian level. Indeed, it has incentives to implement a tax on natural resource which only partially internalizes the externality as young voters (generation 2) bear only one share of the externality in the second period. Moreover, the policy maker has also incentives to subsidize the use of natural resource since it is in a monopolistic position relative to the policy maker of the second period. However, in the presence of altruism towards descendants, the internalization effect is reinforced and the subsidization incentive effect is lowered since generations 1 and 2 care for generation 3. Finally, in a world with multiple countries and no altruism, only remains for the first period policy maker of one country the incentives to implement a subsidy on natural resource as the externality is worldwide and the policy maker does not care for generation 3. This latter result can explain why we observe in practice more governments subsidizing the use of natural resource than taxing it.[4]

The paper contributes to the economics literature related to exhaustible natural re-

[4] The real world is indeed composed of multiple countries and empirical papers suggest that altruism towards descendants is quite low (Hurd, 1989; Kopczuk and Lupton, 2007; Laitner and Juster, 1996; Wilhelm, 1996).

sources, global environmental externalities, discounting, growth sustainability, public policies and political coordination. More specifically, it builds on the strand of literature that develops overlapping generation models. With this type of models, some papers focus on exhaustible natural resources without considering environmental externalities (Agnani et al., 2005; Howarth, 1991; Howarth and Norgaard, 1993; Olson and Knapp, 1997), which means that they deal with equity issues but not with efficiency issues. Other papers focus on global environmental externalities without considering exhaustible resources (Bovenberg and Heijdra, 1998; John and Pecchenino, 1994; Jouvet et al., 2000; Marini and Scaramozzino, 1995). These papers develop a welfare economics approach to analyze policies dealing with environmental externalities, such as a Pigouvian tax. Only a few papers with overlapping generation models include both exhaustible natural resources and global environmental externalities (Babu et al., 1997; Gerlagh and Keyzer, 2001). Those papers also develop a welfare economics approach to analyze policies dealing with environmental externalities. Relative to all the quoted papers, we build a simpler overlapping generation model with only two periods, which enables us to complement this literature by computing an explicit formula for the Pigouvian tax in a welfare economics approach.

A few papers with overlapping generation models take a political economy approach to analyze policies dealing with global environmental externalities (Chiroleu-Assouline and Fodha, 2006; Habla and Roeder, 2017; Karp and Rezai, 2014; Pecchenino, 1995). Our paper complements those papers by computing an explicit formula for a second-best tax. Moreover, our model adds exhaustible natural resources, which gives rise to an empowerment for policy makers to implement subsidies for the use of natural resources. To our knowledge, this is the first paper to explain why democratic policy makers (i.e. without lobbying) might subsidize the use of fossil fuels even in the presence of climate change externality. We also go further than the previous literature by discussing how altruism level and voting power affect the decisions of policy makers. Finally, our paper is the first to disentangle individual pure time preference, individual altruism towards descendant, social welfare weight per generation (welfare economics approach) and voting power weight per generation (political economy approach).

The remainder of the paper is structured as follows. Section 2 presents our modeling assumptions. In Section 3, we determine the decentralized economy given the public policies. Section 4 analyzes the policies chosen by the benevolent social planner. Section 5 analyzes the policies chosen by the democratic policy maker representing the voters, and discusses how altruism level and voting power affect the decisions of the policy maker. Finally, Section 6 concludes.

2 Setting

We consider an intergenerational model with two periods, denoted I and II, and three generations of agents, denoted 1, 2 and 3. Each generation is composed of a continuum of identical agents. Generation 1 is old in period I and dies at the end of period I. A generation 1's agent has an exogenous endowment of exhaustible natural resource $\overline{R} > 0$ at the beginning of period I. Generation 2 is young in period I and old in period II. A generation 2's agent has an exogenous endowment of labour $L = 1$ at the beginning of period I. Generation 3 comes to birth at the beginning of period II and is young in period II. A generation 3's agent has an exogenous endowment of labour $L = 1$ at the beginning of period II.

We assume the existence of the following markets. In period I, we have a market for natural resource with price denoted p_I and a market for consumption good with price 1 (i.e. numéraire of period I). In period II, we have a market for natural resource with price denoted p_{II} and a market for consumption good with price 1 (i.e. numéraire of period II). These four markets are assumed to be efficient. We denote R the amount of natural resource purchased by a generation 2's agent in period I, R_I the quantity used for production in period I and thus $R - R_I$ the quantity saved for period II. With quantity of labour $L = 1$ and quantity of natural resource R_I, the quantity of good produced by a generation 2's agent in period I is assumed to have a Cobb-Douglas form $AR_I^{1-\beta}$, in which $A > 0$ is the total factor productivity and $\beta \in [0, 1]$ is the share of contribution of labor. We denote R_{II} the amount of natural resource purchased by a generation 3's agent in period II. With quantity of labour $L = 1$ and quantity of natural resource R_{II}, the quantity of good produced by a generation 3's agent in period II is assumed to have a Cobb-Douglas form $(1 + g_A)AR_{II}^{1-\beta}$, in which g_A is the growth rate of the total factor productivity A. We also assume that each agent can transfer wealth to its direct descendant. We denote t_{12} and t_{23} the amounts transferred, respectively, in period I from generation 1's agent to her descendant in generation 2 and in period II from generation 2's agent to her descendant in generation 3.

We assume that the use of natural resource R_I in period I has a global externality on generation 3 through the reduction of its production by the amount $D(R_I)$ by agent, where the function D is increasing and convex.

We assume that agents derive utility from their individual consumption and potentially from the utility of their direct descendant for altruistic purpose. Agents of generations 3, 2 and 1 respectively derive utilities:

$$U_3 = u(c_{3II}), \tag{1}$$

$$U_2 = u(c_{2I}) + \frac{1}{1+\rho}u(c_{2II}) + \lambda U_3, \tag{2}$$

$$U_1 = \frac{1}{1+\rho}u(c_{1I}) + \lambda U_2, \tag{3}$$

where the function u is increasing and concave, ρ is an individual pure time preference parameter, λ is a pure altruism parameter, and c_{1I}, c_{2I}, c_{2II} and c_{3II} are respectively the consumption levels of generation 1's agent at period I, generation 2's agent at period I, generation 2's agent at period II and generation 3's agent at period II. Note that, with these modelling assumptions, agents of different generations have similar utility functions. The only difference in the utility formula are due to the fact that the period before period I and the period after period II are not modeled, which explains why generation 1's agents and generation 3's agents have a smaller utility formula than generation 2's agents.

Finally, we assume the possibility of implementing the following policies. We allow for a linear tax on the resource used in period I and we denote τ the tax per unit of resource used in period I (τ might be positive or negative, corresponding to a tax or a subsidy respectively). We allow for lump-sum transfers between agents within each period. For this policy, we denote m_{1I} and m_{2I} the amounts received in period I by agents of generations 1 and 2 respectively, and m_{2II} and m_{3II} the amounts received in period II by agents of generations 2 and 3 respectively (these amounts might be positive or negative).

3 Decentralized economy with policies

In the decentralized economy with policies, agents take prices, tax per resource unit and lump-sum transfers as given and choose natural resource purchases/sells/savings, transfers to descendants and consumption levels as follows:

$$\begin{aligned}\max_{c_{1I},t_{12}} \quad & \frac{1}{1+\rho}u(c_{1I}) + \lambda u(c_{2I}) + \frac{\lambda}{1+\rho}u(c_{2II}) + \lambda^2 u(c_{3II}) \\ & \text{s.t. } \; c_{1I} = p_I\overline{R} - t_{12} + m_{1I}, \\ & \quad c_{2I} + p_I R = AR_I^{1-\beta} + t_{12} + m_{2I} - \tau R_I, \\ & \quad c_{2II} = p_{II}(R - R_I) - t_{23} + m_{2II}, \\ & \quad c_{3II} + p_{II}R_{II} = (1+g_A)AR_{II}^{1-\beta} - D(\tilde{R}_I) + t_{23} + m_{3II}, \\ & \quad t_{12} \geq 0.\end{aligned} \tag{4}$$

$$\begin{aligned}\max_{c_{2I},c_{2II},R,R_I,t_{23}} \quad & u(c_{2I}) + \frac{1}{1+\rho}u(c_{2II}) + \lambda u(c_{3II}) \\ & \text{s.t. } \; c_{2I} + p_I R = AR_I^{1-\beta} + t_{12} + m_{2I} - \tau R_I, \\ & \quad c_{2II} = p_{II}(R - R_I) - t_{23} + m_{2II}, \\ & \quad c_{3II} + p_{II}R_{II} = (1+g_A)AR_{II}^{1-\beta} - D(\tilde{R}_I) + t_{23} + m_{3II}, \\ & \quad t_{23} \geq 0.\end{aligned} \tag{5}$$

$$\begin{aligned}\max_{c_{3II},R_{II}} \quad & u(c_{3II}) \\ & \text{s.t. } \; c_{3II} + p_{II}R_{II} = (1+g_A)AR_{II}^{1-\beta} - D(\tilde{R}_I) + t_{23} + m_{3II}.\end{aligned} \tag{6}$$

Prices p_I and p_{II} are determined such that markets clear at equilibrium and policies have to be financially balanced in periods I and II:

$$\overline{R} = R \tag{7}$$

$$R - R_I = R_{II} \tag{8}$$

$$m_{1I} + m_{2I} - \tau R_I = 0 \tag{9}$$

$$m_{2II} + m_{3II} = 0 \tag{10}$$

The externality is such that:

$$\tilde{R}_I = R_I \tag{11}$$

The eleven endogenous variables $(c_{1I}, c_{2I}, c_{2II}, c_{3II}, R, R_I, R_{II}, t_{12}, t_{23}, p_I, p_{II})$ are determined by eleven conditions. These conditions include the two clearing conditions (7) and (8), and the four first constraints in (4). The five other conditions are the first-order conditions of (4), (5) and (6) (by deriving relative to R, R_I, R_{II}, t_{12} and t_{23}), which can be written:

$$u'(c_{2I})\left(R_I^{-\beta} - \frac{\tau}{A(1-\beta)}\right) = \frac{1}{1+\rho}u'(c_{2II})(1+g_A)(\overline{R} - R_I)^{-\beta} \tag{12}$$

$$p_I = A(1-\beta)R_I^{-\beta} - \tau \tag{13}$$

$$p_{II} = (1+g_A)A(1-\beta)(\overline{R} - R_I)^{-\beta} \tag{14}$$

$$\left\{ t_{12} = 0 \text{ and } \frac{1}{1+\rho} u'(c_{1I}) > \lambda u'(c_{2I}) \right\} \text{ or } \left\{ t_{12} > 0 \text{ and } \frac{1}{1+\rho} u'(c_{1I}) = \lambda u'(c_{2I}) \right\} \tag{15}$$

$$\left\{ t_{23} = 0 \text{ and } \frac{1}{1+\rho} u'(c_{2II}) > \lambda u'(c_{3II}) \right\} \text{ or } \left\{ t_{23} > 0 \text{ and } \frac{1}{1+\rho} u'(c_{2II}) = \lambda u'(c_{3II}) \right\} \tag{16}$$

In the following sections, we analyze the policy choices that would be made by a policy maker. We first focus on the benevolent social planner in the tradition of welfare economics. We then focus on a more realistic democratic policy maker representing the voters in the tradition of political economy. These analyses enable to compute in particular the natural resource tax rate τ that would be implemented in the decentralized economy by the benevolent social planner and the democratic policy maker.

4 Benevolent social planner

In welfare economics, policy recommendations are usually obtained from the theory of the benevolent social planner. In this theory, the objective of a benevolent social planner is to maximize a welfare function, which is usually a weighted sum of the utilities of the different agents in the economy. As standard in welfare economics, we consider weights 1, μ and μ^2 for agents of generations 1, 2 and 3 respectively, where μ is an intergenerationnal pure time preference parameter. With a continuum of countries, the benevolent social planner of one country would represent the agents of the three generations but only from its own country. With one global country, the benevolent social planner would represent the agents of the three generations from all over the world. We focus on the case with one global country. In this case, the benevolent omnipotent omniscient social planner solves:

$$\begin{aligned} \max_{c_{1I}, c_{2I}, c_{2II}, c_{3II}, R_I, R_{II}} \quad & \frac{1}{1+\rho} u(c_{1I}) + (\lambda + \mu) u(c_{2I}) + \frac{(\lambda+\mu)}{1+\rho} u(c_{2II}) + (\lambda^2 + \lambda\mu + \mu^2) u(c_{3II}) \\ \text{s.t.} \quad & c_{1I} + c_{2I} = A R_I^{1-\beta}, \\ & c_{2II} + c_{3II} = (1+g_A) A R_{II}^{1-\beta} - D(R_I), \\ & R_I + R_{II} = \overline{R}. \end{aligned} \tag{17}$$

The endogenous variables $(c_{1I}, c_{2I}, c_{2II}, c_{3II}, R_I, R_{II})$ are determined by the three constraints in (17) and the three first-order conditions of (17) which can be written:

$$\frac{1}{1+\rho}u'(c_{1I}) = (\lambda+\mu)u'(c_{2I}) \tag{18}$$

$$\frac{(\lambda+\mu)}{1+\rho}u'(c_{2II}) = (\lambda^2+\lambda\mu+\mu^2)u'(c_{3II}) \tag{19}$$

$$u'(c_{2I})R_I^{-\beta} = \frac{1}{1+\rho}u'(c_{2II})\left((1+g_A)(\overline{R}-R_I)^{-\beta} + \frac{1}{A(1-\beta)}D'(R_I)\right) \tag{20}$$

In a decentralized economy, the benevolent social planner is not omnipotent and omniscient. However, we can show that it can reach the same objectives with aggregate knowledge and public policies.

Proposition 1 *In the decentralized economy, the global benevolent social planner can implement its targeted Pareto optimal allocation with a tax plus lump-sum transfers across agents. The tax τ per unit of natural resource used in period I is:*

$$\tau = \frac{1}{1+\rho}\frac{u'(c_{2II})}{u'(c_{2I})}D'(R_I). \tag{21}$$

Period I transfers, m_{1I} and m_{2I}, are such that $m_{1I} = -m_{2I} + \tau R_I$ and $\frac{1}{1+\rho}u'(c_{1I}) = (\lambda+\mu)u'(c_{2I})$. Period II transfers, m_{2II} and m_{3II}, are such that $m_{2II} = -m_{3II}$ and $\frac{(\lambda+\mu)}{1+\rho}u'(c_{2II}) = (\lambda^2+\lambda\mu+\mu^2)u'(c_{3II})$.

The tax formula (21) corresponds to the Pigouvian tax, i.e. the marginal damage of natural resource use. This formula includes the discount factor $\frac{1}{1+\rho}\frac{u'(c_{2II})}{u'(c_{2I})}$ since the damage is delayed in time. The discount factor is usually denoted $\frac{1}{1+r}$ where r is called the discount rate. With $u(x) = \frac{x^{1-\alpha}}{1-\alpha}$ and $\frac{c_{2II}}{c_{2I}} = e^{g_c}$, we get in first approximation for the discount rate $r = \rho + \alpha g_c$, which is the standard Ramsey equation. Economists disagree on the value that should be used for ρ and g_c to compute the discount rate value, this contentious debate involving in particular William Nordhaus and Nicholas Stern. The root of the disagreement is the weights that should be used for the different generations in the social welfare function. One issue in the debate is that most of the models do not disentangle individual pure time preference, individual altruism towards descendant and social welfare weight per generation.

For instance, Nordhaus's modelling corresponds to assuming $\mu = \frac{1}{1+\rho}$ and $\lambda = 0$, or $\lambda = \frac{1}{1+\rho}$ and $\mu = 0$, while Stern's modelling corresponds to assuming $\mu = 1$ and $\lambda = 0$, or $\lambda = 1$ and $\mu = 0$. In words, Nordhaus implicitly assumes an intergenerational discount factor (μ) similar to the discount factor of an individual within her lifetime ($\frac{1}{1+\rho}$), and Stern assumes a higher intergenerational discount factor. Or, Nordhaus implicitly assumes an altruism level similar to the discount factor of an individual within her lifetime ($\frac{1}{1+\rho}$), and Stern assumes a higher altruism level. Thus, with these standard modellings which do not disentangle individual pure time preference, individual altruism towards descendant and social welfare weight per generation, all these dimensions directly affect the discount rate through the choice of ρ.

When individual pure time preference, individual altruism towards descendant and social welfare weight per generation are disentangled as in the present model, we see that their impacts on the discount rate are different. Only individual pure time preference has a direct impact. The weights in the welfare function, which is the root of the disagreement between economists on the value of the discount rate r, have only indirect impacts through the marginal utilities $u'(c_{2I})$ and $u'(c_{2II})$. As a Stern-type social planner values more young agents than old agents relative to a Nordhaus-type social planner, $\frac{c_{2II}}{c_{2I}}$ is smaller for the former than for the latter, and $\frac{u'(c_{2II})}{u'(c_{2I})}$ is larger for the former than for the latter, which means that a Stern-type social planner implements a larger tax rate than a Nordhaus-type social planner.

The main limit of the benevolent social planner theory is that the public policy decisions are actually taken by policy makers that might have different objectives. In particular in the present case, contrary to the social planner who is consistent over time, the policy makers of period I and II in a democracy might have different objectives as they are not elected by the same generations. In the following section, we analyze the policy that would be implemented in this context.

5 Democratic policy maker

In a democratic system, the policy maker objective depends on the voters. The recent popular model in political economy, called the probabilistic voting model, shows that the elected policy maker aims at maximizing a social welfare function in which the weights characterize the voting power and sensitivity of the voters (Lindbeck and Weibull 1987, Bierbrauer and Boyer 2016). In our model, it would correspond to a policy maker in period I maximizing a social welfare function without any weight for generation 3 and a policy maker in period II maximizing a social welfare function without any weight for generation 1. In each period, we consider weights 1 and ν for old and young generations respectively. With a continuum of countries, the policy maker of one country would represent the agents of the living generations only from its own country. With one global country, the policy maker would represent the agents of the living generations from all over the world. We focus on the case with one global country. Moreover, the decisions of policy maker I are taken before the decisions of policy maker II, which means that policy maker I anticipates the decision of policy maker II. The decision process can be formalized using a standard backward induction presentation:

Stage II: The global country omnipotent and omniscient policy maker II solves:

$$\begin{aligned} \max_{c_{2II}, c_{3II}, R_{II}} \quad & u(c_{2I}) + \frac{1}{1+\rho} u(c_{2II}) + (\lambda + \nu) u(c_{3II}) \\ \text{s.t.} \quad & c_{2II} + c_{3II} = (1+g_A) A R_{II}^{1-\beta} - D(R_I), \\ & R_{II} = \overline{R} - R_I. \end{aligned} \tag{22}$$

Problem (22) gives the following first-order condition:

$$\frac{1}{1+\rho} u'(c_{2II}) = (\lambda + \nu) u'(c_{3II}) \tag{23}$$

which gives implicitly, with the two constraints in (22), $R_{II}(R_I)$, $c_{2II}(R_I)$ and $c_{3II}(R_I)$, and then by derivation:

$$c'_{2II}(R_I) = -\frac{(\lambda+\nu)u''(c_{3II})}{\frac{1}{1+\rho}u''(c_{2II}) + (\lambda+\nu)u''(c_{3II})} \big(A(1-\beta)(1+g_A)(\overline{R}-R_I)^{-\beta} + D'(R_I)\big), \tag{24}$$

$$c'_{3II}(R_I) = -\frac{\frac{1}{1+\rho}u''(c_{2II})}{\frac{1}{1+\rho}u''(c_{2II}) + (\lambda+\nu)u''(c_{3II})} \big(A(1-\beta)(1+g_A)(\overline{R}-R_I)^{-\beta} + D'(R_I)\big). \tag{25}$$

Stage I: The global country omnipotent and omniscient policy maker I solves:

$$\begin{aligned} \max_{c_{1I}, c_{2I}, R_I} \quad & \frac{1}{1+\rho} u(c_{1I}) + (\lambda+\nu) u(c_{2I}) + \frac{(\lambda+\nu)}{1+\rho} u(c_{2II}) + (\lambda^2 + \lambda\nu) u(c_{3II}) \\ \text{s.t.} \quad & c_{1I} + c_{2I} = A R_I^{1-\beta}, \\ & c_{2II} = c_{2II}(R_I), \\ & c_{3II} = c_{3II}(R_I). \end{aligned} \tag{26}$$

Problem (26) gives the following first-order conditions:

$$\frac{1}{1+\rho} u'(c_{1I}) = (\lambda+\nu) u'(c_{2I}), \tag{27}$$

$$u'(c_{2I})R_I^{-\beta} = -\frac{1}{1+\rho}u'(c_{2II})\frac{1}{A(1-\beta)}c'_{2II}(R_I) - \frac{(\lambda^2+\lambda\nu)}{\lambda+\nu}u'(c_{3II})\frac{1}{A(1-\beta)}c'_{3II}(R_I). \tag{28}$$

In a decentralized economy, the policy makers are not omnipotent and omniscient. However, we can show that they can reach the same objectives with aggregate knowledge and public policies.

Proposition 2 *In the decentralized economy with one global country and a democratic policy maker at each period, the period I policy maker implements the following tax per unit of natural resource use in period I:*

$$\begin{aligned}\tau =& \left[\gamma\frac{1}{1+\rho}\frac{u'(c_{2II})}{u'(c_{2I})} + (1-\gamma)\lambda\frac{u'(c_{3II})}{u'(c_{2I})}\right]D'(R_I)\\ &-\left[\frac{1}{1+\rho}\frac{u'(c_{2II})}{u'(c_{2I})} - \lambda\frac{u'(c_{3II})}{u'(c_{2I})}\right](1-\gamma)A(1-\beta)(1+g_A)(\overline{R}-R_I)^{-\beta},\end{aligned} \tag{29}$$

where $\gamma = \frac{(\lambda+\nu)u''(c_{3II})}{\frac{1}{1+\rho}u''(c_{2II})+(\lambda+\nu)u''(c_{3II})}$ *with* $0 \leq \gamma \leq 1$. *Period I transfers, m_{1I} and m_{2I}, are such that* $m_{1I} = -m_{2I} + \tau R_I$ *and* $\frac{1}{1+\rho}u'(c_{1I}) = (\lambda+\nu)u'(c_{2I})$. *Period II transfers, m_{2II} and m_{3II}, are such that* $m_{2II} = -m_{3II}$ *and* $\frac{1}{1+\rho}u'(c_{2II}) = (\lambda+\nu)u'(c_{3II})$.

For policy maker I, there is an empowerment to implement a tax which partially internalizes the externality since generation 2 will have to share the burden of the externality with generation 3 (term $\gamma\frac{1}{1+\rho}\frac{u'(c_{2II})}{u'(c_{2I})}$ in (29)). This empowerment is reinforced in the case of altruism towards generation 3 (term $(1-\gamma)\lambda\frac{u'(c_{3II})}{u'(c_{2I})}$ in (29)). Without altruism, the internalization remains partial because the burden share effect cannot incentivize to full internalization as generation 2's consumptions in period I and II are not substituable. Moreover, for policy maker I, there is an empowerment to implement a subsidy for natural resource use R_I in period I to over-exploit natural resource in the favour of generations 1 and 2 (term $\frac{1}{1+\rho}\frac{u'(c_{2II})}{u'(c_{2I})}$ in (29)). This empowerment is lowered in the case of altruism towards generation 3 (term $\lambda\frac{u'(c_{3II})}{u'(c_{2I})}$ in (29)).

With $\nu = 0$, a Pareto optimal allocation is reached since the tax formula (29) simplifies to the Pigouvian level (21) with (23). Expecting that a democratic policy maker implements a Pigouvian tax leading to a Pareto optimal allocation thus remains on the hypothesis of all the voting power given to the old generation, which can be seen as paternalism. Indeed, in this case, the reached Pareto optimal allocation is the one that maximizes the altruistic utility of the living old generation and the wealth share obtained by future generations fully relies on the degree of altruism towards descendants (given (23) and (27)). If, in addition to $\nu = 0$, we assume $\lambda = \frac{1}{1+\rho}$, we get back to standard infinitely lived agent models with pure time preference factor ρ. This equivalence requires a high degree of altruism, which is not necessarily true in the real world.

With $\nu > 0$, a Pareto optimal allocation cannot be reached as policy makers I and II do not have the same objectives (i.e. the relative weights of generations 2 and 3 are different for policy makers I and II). In this case, the tax formula (29) is smaller than the Pigouvian formula (21). Note that the numerical value of the implemented tax is not necessarily smaller than the Pigouvian numerical value since the consumption level and marginal utilities are modified. However, the lower the degree of altruism, the lower will be the implemented tax. With low level of altruism, the tax might even be negative, in other words it might be a subsidy. With multiple countries and no altruism towards descendants, the "tax" is for sure a subsidy as there is no empowerment to internalize the externality and there is no reason to lower the empowerment of over-exploiting natural resource. This result can explain why, in the real world, fossil fuels are still highly subsidized despite climate change.

6 Conclusion

The present paper argues that intergenerational coordination is a main issue which partly explains why environmental policies, like a carbon tax for climate change, are not implemented and even why fossil fuel subsidies might be implemented. Thanks to an overlapping generation model with an exhaustible natural resource generating a long-term global environmental externality, we show that an intertemporal global policy maker would implement a Pigouvian tax on the natural resource (welfare economics approach). However, we also demonstrate that a democratic global policy maker would in general implement a tax below the Pigouvian level as the latter policy maker only represents the living generations (political economy approach). In some cases, the democratic policy maker might even subsidize (instead of tax) the use of natural resource to give incentives to living individuals to over-exploit the resource in their benefits. This result can explain why fossil fuel subsidizations are currently in place in the real world despite climate change. Moreover, our results suggest that high altruism towards descendants and high voting power to young generation enable to give more empowerment to the democratic policy maker to implement a tax which better internalizes the externality. While increasing the voting power of young generations would lower the policy failure in term of efficiency, it would however lead to inequity issues by lowering consumption of old generations relative to young generations within each period.

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