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Working Paper 22/374
August 2022

Economics Working Paper Series

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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August 18, 2022

Abstract

An extensive climate policy literature provides various recommendations, but they are not supported democratically since the models employed consider either infinitely-lived individuals or normative social objectives (or both). In contrast, the present paper provides policy recommendations that are able to go through democratic processes. I develop an overlapping generation model with political process micro-foundations. I analyze how democratic policies, which are directly and indirectly related to climate change, differ from standard recommended policies. The novel politico-economic formula derived for the interest rate highlights that individual pure time preference, individual altruism toward descendants, and young generation political power are key determinants of democratic climate policy ambition.

Keywords: Climate change; Discounting; Externality; Overlapping generations; Political economy.

JEL codes: D6; D7; E6; Q5.

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1 Introduction

Climate change mitigation raises fundamental coordination issues: coordination between States (see, e.g., Batabyal (2017) for a literature review) but also between generations. In the long term, greenhouse gas (GHG) emissions generate economic damage through climate change. The Intergovernmental Panel on Climate Change (2021) shows that different scenarios for future GHG emissions differ significantly in terms of their climate change impacts, particularly after 2050. Yet, the literature largely ignores the intergenerational coordination issue: policy prescriptions are based on normative approaches to climate change mitigation that make strong assumptions about present generations' altruistic objectives or commitment capacities (or both) (e.g., Barrage (2018); Harstad (2020); Kotlikoff et al. (2021); Nordhaus (1993); Schneider et al. (2012)). By questioning these strong assumptions, the present paper aims to move the debate to policies that would be democratically acceptable. This is necessary in order to create a common ground where economists and present generations can discuss climate policy choices.

The main contribution of the paper is to study how generational turnover determines democratically acceptable climate policies. To do this, it is crucial to consider intergenerational policies as a whole since climate policy choices are intertwined with other intergenerational policy choices, such as those targeting capital accumulation and wealth redistribution across generations. I develop a tractable overlapping generations (OLG) model in which individuals live for two periods and have an intertemporal additive utility function with a time preference discount factor. Individuals may also demonstrate some pure altruism toward their direct descendants.[1] In this model, the capital used to produce the consumption good can accumulate over time and the production process generates a long-term pollution externality representing climate change. I focus my attention on the intergenerational coordination issue and exclude the international coordination issue by considering one global government in each period. More specifically, policies are determined in each period by a social welfare function in which the weights char-

[1] Altruism toward a descendant is said to be pure if it concerns the total utility of the descendant (Galperti and Strulovici 2017). In other words, with pure altruism toward direct descendants, individuals are indirectly altruistic toward their indirect descendants.

acterize the political power of young and old living individuals.[2] Because of the generational turnover, the democratic social objective is time inconsistent. I show that this time inconsistency combined with the impossibility of committing to future policies leads to sub-optimal policies at the politico-economic equilibrium. This contrasts with the Pareto optimal policies that would be obtained with a standard normative objective featuring a welfare or a Pareto criterion. While the latter objective would lead to the implementation of a pollution emission tax and intratemporal lump-sum transfers across generations, the democratic objective also leads to the implementation of an inefficient capital investment tax to lower the transfer of resources across time. In both the normative and democratic cases, the emission tax is equal to the marginal damage discounted with the market interest rate, which ensures consistency between capital investment and emission abatement for resource transfers over time. Although the emission tax level is efficient in the normative case, it is inefficient in the democratic case since the market interest rate is distorted by the investment tax. I provide an explicit formula for the market interest rate at the politico-economic equilibrium, which highlights that individual pure time preference, individual altruism toward descendants, and young generation political power are key determinants of the emission tax level. My contribution therefore emphasizes the genuine foundations of climate policy ambitions, which opens a discussion on how to strengthen these foundations and echoes the rise of a youth movement supporting climate policies.[3]

The paper contributes to the extensive literature on climate policies. One branch of the literature develops infinitely-lived agent (ILA) models. The most standard ILA model comprises one representative individual who has an intertemporal additive utility function with a constant discount factor, and a social welfare function identical to the utility function of the representative individual (e.g., Acemoglu et al.

[2]The assumption of the weights characterizing political power can be micro-founded with a probabilistic voting model (Coughlin and Nitzan 1981; Lindbeck and Weibull 1987). The relative political power between two living generations may characterize their relative size and relative ideological strength. See for instance Gonzalez-Eiras and Niepelt (2008); Hassler et al. (2005); Karp and Rezai (2014); Lancia and Russo (2016) for OLG models in which the democratic social objective is micro-founded with a probabilistic voting model.

[3]See for instance https://globalclimatestrike.net and https://fridaysforfuture.org regarding the rise of a youth movement supporting climate policies.

(2012); Dietz et al. (2018); Golosov et al. (2014); Nordhaus (2013)). The standard ILA model can be seen as a specific case of my model in which individuals care as much about the consumption of their direct descendants in a given period as about their own consumption in the same period, and where young generations have no political power.[4] My formula for the market interest rate corresponds in this case to the standard Keynes-Ramsey rule. My paper complements this branch of literature by disentangling individual altruism toward descendants from individual pure time preference and by studying the role played by young generation political power, which generates inefficiencies.

Some papers deviate from the standard ILA model and consider a non-constant discount factor to characterize the potential time inconsistency of individual preferences or the turnover of politicians in power (e.g., Gerlagh and Liski (2018); Harstad (2020); Iverson and Karp (2021)). This deviation generates inconsistent objectives and strategic behavior between successive governments.[5] My model also features inconsistent objectives and strategic behavior but for a different reason, namely the turnover and overlapping of generations.

Other papers deviate from the standard ILA model and consider a higher discount factor in the social welfare function than in the individual utility function, which leads to capital investment subsidies and more ambitious climate policies (e.g., Barrage (2018); Belfiori (2017); van der Ploeg and Rezai (2019)). The assumption of a higher social discount factor is based on a normative approach of intergenerational social objectives.[6] By contrast, I consider democratic social objectives, which leads to the opposite result, with capital investment taxes and less ambitious climate policies.

The paper also complements the branch of climate policy literature that develops OLG models. In this branch, some papers assume a normative welfare criterion for the social objective, which involves maximizing a social welfare function includ-

[4] See also Barro (1974); Kotlikoff et al. (2021); Schneider et al. (2012) on why ILA models can only be a good stylized representation of overlapping generations in specific cases.

[5] See Millner and Heal (2018); Strotz (1955) for more details on social welfare functions and the inconsistency of objectives between successive governments.

[6] See Bernheim (1989); Farhi and Werning (2007) on why a normative approach of social objectives with overlapping generations favors a higher discount factor in the social welfare function.

ing all generations (e.g., Howarth and Norgaard (1992); Marini and Scaramozzino (1995); Schneider et al. (2012)). Other papers assume a normative Pareto criterion, which involves targeting a Pareto improvement including all generations (e.g., Andersen et al. (2020); Bovenberg and Heijdra (1998); Kotlikoff et al. (2021)). In line with these papers, I show that normative criteria lead to a Pareto optimal allocation when a sufficiently rich set of public policies is considered. Since public debt plays a neutral role in the presence of lump-sum transfers (Calvo and Obstfeld 1988), it is sufficient to consider a climate policy and lump-sum transfers as I do.[7] Unlike the normative criteria, the democratic approach I consider takes into account the fact that policies are chosen in each period by living generations without the possibility of committing to future policies. To my knowledge, in the branch of literature on climate policies with OLG models, only Karp and Rezai (2014) also consider a democratic approach. In their model, individuals are selfish, climate policies are studied independently from other intergenerational policies, and the democratic approach is solved numerically. While these authors provide an interesting first step with which to study democratic climate policies, my paper is an important step forward. It considers individual altruism toward descendants, which allows us to include ILA models as a specific case and to highlight the important role of altruism. Moreover, I take into account the intertwining between climate policies and other intergenerational policies, such as those related to capital accumulation and wealth redistribution across generations. Last but not least, the tractability of my model highlights the mechanisms at play in democratic climate policy choices.

Finally, my paper also contributes to the literature on the political economy of overlapping generations' economies, which focuses on intergenerational issues other than climate change, such as pensions, education, and risk sharing (e.g., Cooley and Soares (1999); Gonzalez-Eiras and Niepelt (2008); Hassler et al. (2005); Kotlikoff and Rosenthal (1993); Lancia and Russo (2016); Mateos-Planas (2008)). In line with this literature, the political processes in my model lead to policy inefficiencies since generations yet to be born cannot vote and governments have incen-

[7] Howarth and Norgaard (1992); Marini and Scaramozzino (1995) also consider a climate policy and lump-sum transfers, while Andersen et al. (2020); Kotlikoff et al. (2021) consider public debt instead of lump-sum transfers.

tives to reduce the transfer of resources to the future. I complement this literature by providing a novel politico-economic formula, or augmented Keynes-Ramsey rule, for the market interest rate, and by studying the interactions between climate policies and other intergenerational policies.

The remainder of the paper is structured as follows. In Section 2, I present my modeling assumptions. Section 3 studies the normative approach for policy choices. In Section 4, I analyze the democratic approach for policy choices. Section 5 concludes.

2 Setting

I consider an overlapping generation (OLG) model with two periods, denoted as 1 and 2, and three generations of agents, denoted as a, b, and c. Each generation is composed of a continuum of identical agents of mass one. In period 1, agent a is old, her direct descendant agent b is young, and her indirect descendant agent c is not yet born. In the following period 2, agent a is dead, agent b is alive and old, and agent c is alive and young. The first reason for considering such a simple setting is that climate change raises the question of our ability to reduce GHG emissions over the next 30 years, specifically in terms of avoiding catastrophic impacts in the second part of the century (Intergovernmental Panel on Climate Change 2021). As a first approximation, this can be seen as two periods and three generations. The second reason is that this simple setting is sufficient to provide key insights into the intergenerational coordination issue.

In period 1, the old agent a is exogenously endowed with $\overline{K} > 0$ units of capital, while the young agent b is exogenously endowed with one unit of labor. In period 2, the old agent b is endogenously endowed with capital, while the young agent c is exogenously endowed with one unit of labor. The endogenous amount of capital of old agent b in period 2 depends on her capital accumulation from period 1.

There is a unique consumption good, which is produced with capital and labor. The production function at a given period $t \in \{1,2\}$ is assumed to have a Cobb-Douglas form $A_t K_t^{\alpha} L_t^{1-\alpha}$, in which $K_t \geq 0$ is the capital used, $L_t \geq 0$ is the labor used, $A_t > 0$ is the exogenous total factor productivity, and $\alpha \in [0,1]$ is the exogenous constant capital share. The good produced in period 1 can be consumed directly or invested in capital for period 2. The capital depreciates at the exogenous rate δ from period 1 to period 2. The good produced in period 2 can only be consumed. In each period, production is assumed to be performed by young agents, which avoids introducing firms unnecessarily.[8]

Producing the good in the first period generates a pollution emission, which lowers production of the good in the second period. Production $A_1 K_1^{\alpha} L_1^{1-\alpha}$ in period 1 generates the emission $\sigma A_1 K_1^{\alpha} L_1^{1-\alpha}$, where σ is the exogenous emission level per good production unit. An emission abatement effort E_1 can be made in period 1 at an increasing and convex cost $\mathscr{C}(E_1)$. The net emission $\sigma A_1 K_1^{\alpha} L_1^{1-\alpha} - E_1$ in period 1 reduces production of the good in period 2 by the amount $\mathscr{D}(\sigma A_1 K_1^{\alpha} L_1^{1-\alpha} - E_1)$, in which $\mathscr{D}(.)$ is increasing and convex.

Capital and final good markets are assumed to exist in each period, and pollution is an externality. The consumption good is assumed to be the numéraire in each period, and the price of capital is denoted as $1+r_1$ and $1+r_2$ in periods 1 and 2, respectively. In other words, r_2 characterizes the capital market interest rate from period 1 to period 2. Note that we do not need to model labor markets since the young agents are assumed to produce the good in each period .

I consider a large set of policies so that governments are not policy constrained, in the sense that if a welfare or Pareto normative criterion were to be chosen for policy choices, a Pareto optimal allocation would be reached (see Corollary 1 in Section 3). For policies directly affecting the intratemporal allocation of resources, I allow for (positive or negative) lump-sum transfers to agents within each period. I denote by M_{1a} and M_{1b} the amounts received in period 1 by agents a and b respectively, and by M_{2b} and M_{2c} the amounts received in period 2 by agents b and c respectively.[9] In terms of policies directly affecting the intertemporal allocation of

[8] Assuming that the good is produced by the young agent, rather than by a representative competitive firm, simplifies the presentation and does not change the politico-economic equilibrium.

[9] In my setting, I could have additionally assumed that each old agent may choose to make a direct wealth transfer to her direct descendant. However, this direct transfer would be null in the political economy setting considered. Lump-sum transfer policies obtained in the politico-economic equilibrium would in fact wipe out direct transfers since the weight for young agents in the social welfare function is composed of an altruism factor and a political factor, while the weight for young agents in the old agents' utility function is only composed of the altruism factor.

resources, I allow for capital investment and emission abatement policies in period 1. I assume a linear tax on capital investment, with the tax per unit of investment denoted by τ_I, and a linear tax on pollution emission, with the tax per unit of emission denoted by τ_E.[10] The signs of τ_I and τ_E may be positive (i.e., a tax) or negative (i.e., a subsidy). I do not consider a debt instrument (which would allow to transfer public funds from one period to another). As highlighted by Calvo and Obstfeld (1988), a debt instrument plays a neutral role in the presence of intratemporal lump-sum transfers and capital markets.

Agents are assumed to derive utility from their individual consumption and potentially from the utility of their direct descendant for altruistic purposes. I assume the same utility functional form for agents of any generation. The utility of agent i living at periods t and $t+1$ is assumed to be:

$$U_i = u(C_{ti}) + \beta u(C_{t+1i}) + \beta \lambda U_{i+1}, \tag{1}$$

where U_i and U_{i+1} are the utility levels of agent i and her direct descendant,[11] C_{ti} and C_{t+1i} are the consumption levels of agent i in periods t and $t+1$, the function $u(.)$ is increasing and concave, the exogenous discount factor β characterizes the individual pure time preference for the future relative to the present, and the exogenous factor λ characterizes the individual's altruism toward her direct descendant. In my model, the utility functional form actually simplifies for agents a and c since the periods preceding period 1 and following period 2 are not modeled. Thus, agents a, b, and c respectively derive the utilities:

$$U_a = u(C_{1a}) + \lambda U_b, \tag{2}$$

$$U_b = u(C_{1b}) + \beta u(C_{2b}) + \beta \lambda U_c, \tag{3}$$

$$U_c = u(C_{2c}). \tag{4}$$

[10]The pollution tax could be replaced by a cap-and-trade policy without affecting any results in the paper, since none of the features of the model make one policy different from the other.

[11]In line with Galperti and Strulovici (2017) I consider pure altruism, in the sense that if agent a is altruistic toward her direct descendant (i.e., agent b), agent a weighs the total utility of agent b in her own utility. This means that if agent b is also altruistic toward her own descendant (i.e., agent c), agent a indirectly weighs the utility of agent c in her own utility.

Finally, I build on probabilistic voting models for political processes that determine policy choices (Coughlin and Nitzan 1981; Lindbeck and Weibull 1987). Probabilistic voting models tell us that the elected government chooses policies maximizing a social welfare function in which the weights given to a group of identical individuals characterize their political power.[12] I thus assume that the government in each period (hereafter called governments 1 and 2) aims to maximize a social welfare function in which the weight given to each generation characterizes its political power. Similar modeling with overlapping generations and a democratic social objective can be found in Gonzalez-Eiras and Niepelt (2008); Hassler et al. (2005); Karp and Rezai (2014); Lancia and Russo (2016), for instance. For the social welfare function of a given period, I provide a unit weight for the old generation's welfare and denote by μ the weight for the young generation's welfare. In other words, μ characterizes the political power of the young generation relative to the old generation. Note that the governments in periods 1 and 2 represent partially different generations and have inconsistent objectives, thereby generating suboptimal policy choices in the politico-economic equilibrium. Before studying this equilibrium, I analyze the policy choices obtained with a normative approach as a benchmark.

3 Normative policies

In this section, I consider the decentralized economy with given policies and analyze the policy choices satisfying either a welfare or a Pareto criterion. Individuals make choices in each period to maximize their present and future utility flows under their budget constraint. They are price and policy takers, and they anticipate their future consumption as a function of prices, policies, and their previous decisions. Markets clear in each period. I denote by K_1 the capital purchased by agent b in period 1, by I_1 the capital investment made by agent b in period 1, by E_1 the emission abatement undertaken by agent b in period 1, and by K_2 the capital purchased by

[12] The political power of a group depends on the number of voters and on their ideological strength. When there are more voters in a group, its political power will be higher. When the group's ideological preferences are weak, political candidates will make considerable efforts to attract the group's voters and the group's political power will therefore be higher.

agent c in period 2. The decision process is formalized using a backward induction presentation.

In period 2, the choices of agents b and c are respectively characterized by:

$$\begin{aligned} \max_{C_{2b}} \;& u(C_{2b}) + \lambda U_c \\ \text{s.t. } & C_{2b} = (1+r_2)((1-\delta)K_1 + I_1) + M_{2b}, \end{aligned} \tag{5}$$

$$\begin{aligned} \max_{C_{2c},K_2} \;& u(C_{2c}) \\ \text{s.t. } & C_{2c} + (1+r_2)K_2 = A_2K_2^{\alpha} - \mathscr{D}(\sigma A_1 K_1^{\alpha} - E_1) + M_{2c}. \end{aligned} \tag{6}$$

The constraints in (5) and (6) are the budget constraints. The expense of agent b is the consumption C_{2b}, while her revenue is composed of capital earnings plus a lump-sum transfer. The expense of agent c is the consumption C_{2c} and the capital purchase K_2, while her revenue is composed of net production value (i.e., production minus emissions damage) plus a lump-sum transfer. The clearing condition of the capital market is:

$$K_2 = (1-\delta)K_1 + I_1. \tag{7}$$

In period 1, the choices of agents a and b are respectively characterized by:

$$\begin{aligned} \max_{C_{1a}} \;& u(C_{1a}) + \lambda U_b \\ \text{s.t. } & C_{1a} = (1+r_1)\overline{K} + M_{1a}, \end{aligned} \tag{8}$$

$$\begin{aligned} \max_{C_{1b},K_1,I_1,E_1} \;& u(C_{1b}) + \beta u(C_{2b}) + \beta\lambda U_c \\ \text{s.t. } & C_{1b} + (1+r_1)K_1 = A_1K_1^{\alpha} - \mathscr{C}(E_1) - \tau_E(\sigma A_1K_1^{\alpha} - E_1) - I_1 - \tau_I I_1 + M_{1b}, \\ & C_{2b} = (1+r_2)((1-\delta)K_1 + I_1) + M_{2b}. \end{aligned} \tag{9}$$

The first constraints in (8) and (9) are the budget constraints. The expense of agent a is the consumption C_{1a}, while her revenue is composed of capital earnings plus a lump-sum transfer. The expense of agent b is the consumption C_{1b} and the capital purchase K_1, while her revenue is composed of net production value (i.e., production minus the abatement cost, emissions tax, investment, and investment tax) plus a lump-sum transfer. The second constraint in (9) corresponds to the expected period 2 consumption as a function of period 2 prices, period 2 policies, and the agent's decisions in period 1. The latter constraint is directly derived from (5). Note that the first-order conditions of (9) relative to I_1 and E_1 can be respectively written as:

$$u'(C_{1b}) = \frac{1}{1+\tau_I}\beta(1+r_2)u'(C_{2b}), \tag{10}$$

$$\mathscr{C}'(E_1) = \tau_E. \tag{11}$$

Equation (10) is the Euler equation that characterizes the trade-off between consumption in young age and old age for generation b. Compared with a standard Euler equation, it is slightly modified by the potential presence of an investment tax τ_I. Equation (11) shows that the emission abatement is chosen such that its marginal cost equalizes the emission tax τ_E. In particular, no abatement is undertaken if there is no emission tax. Finally, the clearing condition of the capital market is:

$$K_1 = \overline{K}. \tag{12}$$

The economic equilibrium with given public policies is characterized by (5), (6), (7), (8), (9), and (12).

Proposition 1. *In a decentralized economy, any Pareto optimal allocation can be achieved with lump-sum transfers, a null investment tax $\tau_I = 0$, and an emission tax $\tau_E = \frac{1}{1+r_2}\mathscr{D}'(\sigma A_1 K_1^\alpha - E_1)$, which together satisfy the following policy budget balances:*

$$M_{2b} + M_{2c} = 0, \tag{13}$$

$$M_{1a} + M_{1b} - \tau_E(\sigma A_1 K_1^\alpha - E_1) - \tau_I I_1 = 0. \tag{14}$$

Proposition 1 is proved in Appendix A.1, given a standard definition of Pareto optimal allocations. It shows that the set of public policies considered would be sufficient to reach any Pareto optimal allocation. While the share of wealth between generations is managed by intratemporal lump-sum transfers and capital markets, the Pareto optimality is ensured by a null investment tax and an emission tax equal to the marginal damage discounted with the market interest rate. An investment tax should not be introduced in this case because capital markets are efficient, but an emission tax should be introduced since pollution emissions represent an externality. The emission tax must be equal to the marginal damage discounted with the market interest rate to ensure consistency between capital investment and emission abatement for resource transfers to the second period. It is important to note that the interest rate and the emission tax levels strongly depend on the Pareto optimal allocation and thus on the lump-sum transfers: the higher the share for later generations, the lower the interest rate, and the higher the emission tax.[13]

Corollary 1. *In a decentralized economy, a Pareto optimal allocation is reached if we implement policies satisfying a welfare or a Pareto criterion.*

Corollary 1, which can be directly deduced from Proposition 1, shows that Pareto optimal policies could be implemented in the decentralized economy by a time-committed government with a normative objective featuring a welfare or a Pareto criterion. With a welfare criterion, the government would be able to choose policies that lead to the desired Pareto optimal allocation. With a Pareto criterion, the government would be able to implement Pareto-improving policies as long as the allocation achieved is not Pareto optimal. Since the climate policy level depends on the Pareto optimal allocation achieved, it depends on the characteristics of the arbitrarily chosen normative objective. Furthermore, the policies derived from the normative objective have no reason to go through political processes. Political processes generate successive governments that have inconsistent objectives because of the turnover and overlapping of generations. Strategic behavior between successive governments will thus lead to suboptimal policies. The next section analyzes the policy choices obtained in this context in order to provide policy recommendations that can be supported democratically.

[13] Howarth and Norgaard (1992, 1993) further analyze how the interest rate and the emission tax levels depend on the Pareto optimal allocation achieved.

4 Democratic policies

In this section, I consider a decentralized economy with political process microfoundations and analyze the politico-economic equilibrium. Similar to the previous section, individuals make choices in each period to maximize their present and future utility flows under their budget constraint. They are price and policy takers, and they anticipate their future consumption as a function of prices, policies, and their previous decisions. Markets clear in each period. Furthermore, governments make choices in each period to maximize their objective function under the constraint of a policy budget balance. In line with probabilistic voting models, a government's objective function is a weighted sum of living generations' present and future utility flows, in which the weight given to each generation characterizes its political power. I assume a unit weight for the old generation's welfare and a weight denoted by μ for the young generation's welfare. Governments take into account individuals' reactions to policy choices. The first-period government can also anticipate the policy choices of the second-period government as a function of its own policy choices. The decision process is formalized using a backward induction presentation. Given the similarities with the decentralized economy of the previous section for individual choices, the second-period and first-period governments solve respectively:

$$\max_{M_{2b},M_{2c}} \; u(C_{2b}) + \lambda U_c + \mu u(C_{2c}) \quad \text{s.t. } (5),\ (6),\ (7) \text{ and } (13). \tag{15}$$

$$\max_{M_{1a},M_{1b},\tau_E,\tau_I} \; u(C_{1a}) + \lambda U_b + \mu \Big(u(C_{1b}) + \beta u(C_{2b}) + \beta\lambda U_c \Big) \quad \text{s.t. } (5),\ (6),\ (7),\ (8),\ (9),\ (12),\ (13),\ (14), \text{ and } (15). \tag{16}$$

The politico-economic equilibrium is characterized by (15) and (16).

Proposition 2. *The politico-economic equilibrium satisfies:*

$$u'(C_{2b}) = (\lambda+\mu)u'(C_{2c}), \tag{17}$$

$$u'(C_{1a}) = (\lambda+\mu)u'(C_{1b}), \tag{18}$$

$$\tau_I = \frac{1}{1 + \frac{u'(C_{2b})}{u''(C_{2b})}\frac{u''(C_{2c})}{u'(C_{2c})}} \frac{\mu}{\lambda + \mu}, \tag{19}$$

$$\tau_E = \frac{1}{1 + r_2} \mathscr{D}'(\sigma A_1 K_1^{\alpha} - E_1). \tag{20}$$

Proposition 2 is proved in Appendix A.2. Equations (17) and (18) characterize how the relative political power and the individual preference characteristics determine the intratemporal lump-sum transfers across generations. The factor $\lambda + \mu$ in (17) and (18) shows that the young generation's political power μ and the individual altruism toward descendants λ favor lump-sum transfers toward the young generation. Equation (19) characterizes the investment tax chosen by government 1. Although generations b and c both live and vote in period 2, in period 1 generation b lives and votes but generation c does not. Government 1 thus puts less weight on generation c relative to generation b than government 2 does. If government 1 is not strategic with respect to future policies, the investment tax will be null. With strategic behavior, government 1 anticipates that government 2 will transfer too much wealth to the new-born generation c (which votes in the second period but not in the first). Government 1 thus has incentives to implement an investment tax that lowers the transfer of resources to the second period. If the young generation's political power μ rises, the inconsistency of objectives between successive governments will rise, as will the inefficient investment tax. By contrast, individual altruism toward descendants λ eases the inconsistency of objectives and the investment tax. These effects are summarized by the factor $\frac{\mu}{\lambda+\mu}$ in (19). Finally, equation (20) shows that the emission tax is chosen to equal the marginal damage discounted with the market interest rate. This tax level ensures consistency between capital investment and emission abatement for resource transfers to the second period. The following proposition details how the market interest rate, and thus the emission tax, depend on the relative political power and on the individual preference characteristics.

Proposition 3. *With the isoelastic utility function $u(x) = \frac{x^{1-\eta}-1}{1-\eta}$, the market interest* *rate in the politico-economic equilibrium is such that:*

$$\frac{1}{1+r_2}=\frac{\beta}{(1+g)^{\eta}}(\lambda+\mu)\frac{1+(\lambda+\mu)^{\frac{1}{\eta}}}{1+(\lambda+\mu)^{\frac{1}{\eta}}+(\lambda+\mu)^{\frac{1-\eta}{\eta}}\mu}, \tag{21}$$

where $g=\frac{C_{2b}+C_{2c}}{C_{1a}+C_{1b}}-1$ *is the consumption growth rate from period* 1 *to period* 2.

Proposition 3 is proved in Appendix A.3. With an infinitely-lived agent model, the market interest rate would follow the standard Keynes-Ramsey rule $\frac{1}{1+r_2}=\frac{\beta}{(1+g)^{\eta}}$ (more frequently written as $r_2=\rho+\eta g$ with $\rho=-\ln(\beta)$, using a Taylor expansion).[14] By modeling overlapping generations and considering political process micro-foundations, the present paper disentangles the discount factor β of the infinitely-lived agent model into three factors: individual pure time preference β, individual altruism toward descendants λ, and young generation political power μ. The standard Keynes-Ramsey rule corresponds to a specific case of my model in which individuals have a discount factor β, they care the same way about their future consumption and that of their descendants (i.e., $\lambda=1$), and young generations have no political power (i.e., $\mu=0$). Equation (21) thus corresponds to an augmented politico-economic Keynes-Ramsey rule that highlights the impacts of individual altruism toward descendants λ and young generation political power μ on the market interest rate. If government 1 is not strategic relative to future policies, the augmented Keynes-Ramsey rule will be $\frac{1}{1+r_2}=\frac{\beta}{(1+g)^{\eta}}(\lambda+\mu)$. In this case, individual altruism toward descendants λ and young generation political power μ play a similar role, favoring a low interest rate. They promote lump-sum transfers toward the young generation within each period. The individuals of generation b are thus relatively rich in the first period (when young) and relatively poor in the second period (when old), which is associated with high capital investments and a low interest rate. If government 1 is strategic relative to future policies, the augmented Keynes-Ramsey rule has an additional term and is written as in (21). The additional term differentiates the roles of individual altruism toward descendants λ and young generation political power μ. On the one hand, young generation political power

[14]See equation (2.11) in Barro and Sala-i Martin (2004) for the standard Keynes-Ramsey rule of an infinitely-lived agent model.

exacerbates the inconsistency of objectives between successive governments, which promotes a high investment tax and a high interest rate. On the other hand, individual altruism toward descendants eases the inconsistency of objectives between successive governments, which favors a low investment tax and a low interest rate.

I finally present a numerical application to show the significant impacts of individual altruism toward descendants and young generation political power on the market interest rate level and thus on the emission tax level. I assume that one period of the overlapping generation model lasts 35 years, $\overline{K} = 0.7, A_1 = 1, A_2 = 2.2,$ $\alpha = 0.4,\ \delta = 1,\ \sigma = 1,\ \mathscr{C}(x) = 0.2x^2,\ \mathscr{D}(x) = 0.2x^2,\ \beta = 0.7,$ and $\eta = 1$ (i.e., $u(x) = \ln(x)$). I run the numerical application for different levels of individual altruism toward descendants λ and young generation political power μ, as shown in Figure 1.

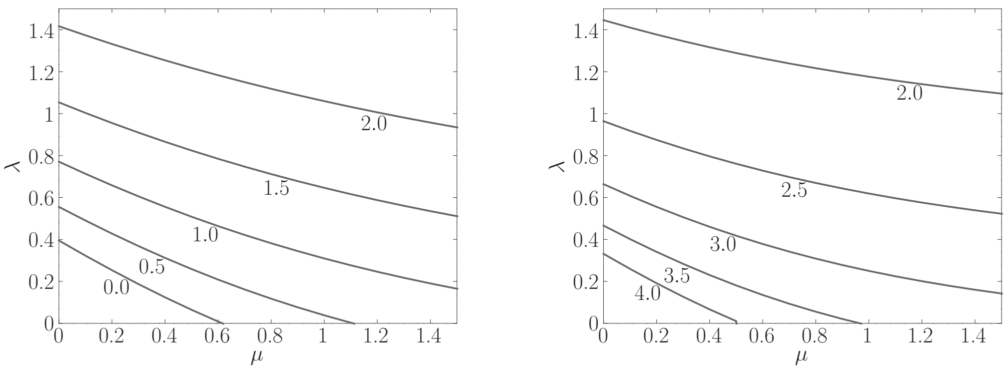

Figure 1: Isoquant curves for different consumption growth rates (left figure) and different market interest rates (right figure), as a function of young generation political power μ and individual altruism toward descendants λ. The value next to each curve is the consumption growth rate expressed as an annual percentage (left figure) and the market interest rate expressed as an annual percentage (right figure).

As expected, Figure 1 highlights that as individual altruism toward descendants λ (y axis) rises, the consumption growth rate (left graph) rises, and the market interest rate (right graph) falls. The figure also highlights that as young generation political power μ (x axis) rises, the consumption growth rate rises, and the market interest rate falls. This shows that the wealth reallocation effect toward later generations through lump-sum transfers dominates the inefficient investment tax effect. Thus, an increase in young generation political power leads to an increase in the emission tax. In contrast, the Karp and Rezai (2014) numerical politico-economic model shows that an increase in young generation political power leads to a decrease in the climate policy level. In their model, the climate policy alone plays the role of reducing the transfer of resources to the future if objectives are inconsistent across successive governments. However, this neglects the fact that other policy tools such as those related to capital accumulation can be used to reduce the transfer of resources to the future. By taking into account the changes in other policy tools, I show that an increase in young generation political power leads to an increase in the climate policy level. This result seems more in line with the rise of a youth movement supporting the implementation of climate policies.[15]

Figure 1 also highlights that individual altruism toward descendants λ and young generation political power μ can have a considerable impact on the market interest rate and the emission tax levels. While low factors of $\lambda = \mu = 0.2$ lead to an annual consumption growth rate below 0% and an annual interest rate above 4%, high factors of $\lambda = \mu = 1.2$ lead to an annual consumption growth rate above 2% and an annual interest rate below 2%.[16] Moreover, the difference in impact between altruism toward descendants λ and young generation political power μ can be significant. The case with $\lambda = 0$ and $\mu = 1$, corresponding to the overlapping generation model with selfish individuals and balanced political power, gives an annual consumption growth rate of around 0.5% and an annual interest rate of around 3.5%, while the case with $\lambda = 1$ and $\mu = 0$, corresponding to the infinitely-lived agent model, gives a higher annual consumption growth rate of around 1.5% and a lower annual interest rate of around 2.5%. In a nutshell, these results show that the implementation of ambitious climate policies rests on the rise of a political youth

[15] See for instance https://globalclimatestrike.net and https://fridaysforfuture.org regarding the rise of a youth movement supporting the climate. Surveys have also shown that younger generations are more concerned by climate change than older generations and are more willing to accept climate policies (e.g., Douenne and Fabre (2020); Whitmarsh (2011)).

[16] Note that an increase in the consumption growth rate from 0% to 2% generates a roughly similar increase in the interest rate through the intertemporal inequality aversion effect $(1+g)^{\eta}$ in (21) (given that $\eta = 1$). Without this effect, the change from $\lambda = \mu = 0.2$ to $\lambda = \mu = 1.2$ would actually lead to an additional decrease of 2 basis points in the interest rate.

movement and even more on an increase in altruism toward descendants.

5 Conclusion

The majority of the literature provides climate policy recommendations that would not be able to go through democratic processes since the models used consider either infinitely-lived individuals or normative social objectives (or both). By contrast, this paper has focused on climate policies that can go through democratic processes to provide democratically acceptable climate policy recommendations. I have shown how democratic climate policies should be intertwined with other intergenerational policies (i.e., intratemporal transfers across generations and policies related to capital accumulation). I have also demonstrated that democratic climate policy ambitions are highly dependant on young generation political power and on individual altruism toward descendants.

The paper lays the foundations for a larger debate on the crucial question of democratic climate policies. To feed the debate, it would be interesting to explore extensions of my model by considering, for instance, more than two periods and three generations, more detailed climate change modeling, consumption good multiplicity, intragenerational heterogeneity, technological change, and uncertainty. Moreover, the paper points out crucial levers of democratic climate policy ambition that we should focus on if we want to increase this ambition. More specifically, we should focus on how to stimulate individual altruism toward descendants and how to increase young generation political power.

Acknowledgements

I am grateful to Antoine Bommier, Jean-Marc Bourgeon, Pierre Boyer, Philippe Colo, Jeanne Commault, Thomas Douenne, Adrien Fabre, Bård Harstad, Daniel Heyen, Frank Krysiak, Jérémy Laurent-Lucchetti, Ralph Winkler, and Yanos Zylberberg for their helpful and generous comments. I thank the seminar participants at ETH Zürich, Aix Marseille School of Economics, Ecole Polytechnique, and

AgroParisTech, and the conference participants at EAERE and SURED. Finally, I would like to thank Becky Rawlings for proofreading the article.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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A Appendices

A.1 Proof of Proposition 1

By definition, an allocation $(C_{1a}, C_{1b}, C_{2b}, C_{2c}, I_1, E_1)$ is Pareto optimal if there exists (ν_b, ν_c) such that:

$$\begin{aligned}\max_{C_{1a}, C_{1b}, C_{2b}, C_{2c}, I_1, E_1} \quad & u(C_{1a}) + (\lambda + \nu_b) u(C_{1b}) + (\lambda + \nu_b)\beta u(C_{2b}) + (\lambda^2 + \lambda \nu_b + \nu_c)\beta u(C_{2c}) \\ \text{s.t.} \quad & C_{1a} + C_{1b} = A_1 \overline{K}^{\alpha} - \mathscr{C}(E_1) - I_1, \\ & C_{2b} + C_{2c} = A_2((1-\delta)\overline{K} + I_1)^{\alpha} - \mathscr{D}(\sigma A_1 \overline{K}^{\alpha} - E_1).\end{aligned} \tag{22}$$

By deriving the first order conditions of (22), $(C_{1a}, C_{1b}, C_{2b}, C_{2c}, I_1, E_1)$ achieves a Pareto optimal allocation if and only if there exists (ν_b, ν_c) such that:

$$C_{1a} + C_{1b} = A_1 \overline{K}^{\alpha} - \mathscr{C}(E_1) - I_1, \tag{23}$$

$$C_{2b} + C_{2c} = A_2((1-\delta)\overline{K} + I_1)^{\alpha} - \mathscr{D}(\sigma A_1 \overline{K}^{\alpha} - E_1), \tag{24}$$

$$u'(C_{1a}) = (\lambda + \nu_b) u'(C_{1b}), \tag{25}$$

$$(\lambda + \nu_b) u'(C_{2b}) = (\lambda^2 + \lambda \nu_b + \nu_c) u'(C_{2c}), \tag{26}$$

$$u'(C_{1b}) = \beta u'(C_{2b}) \alpha A_2((1-\delta)\overline{K} + I_1)^{\alpha - 1}, \tag{27}$$

$$u'(C_{1b}) \mathscr{C}'(E_1) = \beta u'(C_{2b}) \mathscr{D}'(\sigma A_1 \overline{K}^{\alpha} - E_1). \tag{28}$$

Let us now show that in the decentralized economy any Pareto optimal allocation can be reached thanks to lump-sum transfers, a null investment tax $\tau_I = 0$ and an emission tax $\tau_E = \frac{1}{1+r_2} \mathscr{D}'(\sigma A_1 K_1^{\alpha} - E_1)$, satisfying policy budget balances (13) and (14). The first-order conditions of (6) and (9) are:

$$1 + r_2 = \alpha A_2 K_2^{\alpha - 1}, \tag{29}$$

$$u'(C_{1b}) = \frac{1}{1 + \tau_I} \beta (1 + r_2) u'(C_{2b}), \tag{30}$$

$$\mathscr{C}'(E_1) = \tau_E, \tag{31}$$

$$1 + r_1 = (1 - \tau_E \sigma)\alpha A_1 K_1^{\alpha-1} + (1-\delta)(1+\tau_I). \tag{32}$$

Combining the policy budget constraint (14), the market clearing condition (12), the first constraints of (8) and (9), and $\tau_I = 0$, I get (23). Combining the policy budget constraint (13), the market clearing conditions (7) and (12), and the constraints of (5) and (6), I get (24). Combining (30) with (7), (12), (29) and $\tau_I = 0$, I get (27). Combining (30) with $\tau_E = \frac{1}{1+r_2}\mathscr{D}'(\sigma A_1 K_1^{\alpha} - E_1)$, $\tau_I = 0$, (12) and (31), I get (28). Finally, for any given v_b and v_c, I can choose (M_{1a}, M_{1b}) and (M_{2b}, M_{2c}) such that (25) and (26) are satisfied respectively. This concludes the proof.

A.2 Proof of Proposition 2

A politico-economic equilibrium is a subgame perfect Nash equilibrium and is solved backward.

A.2.1 Second period

The government's problem (15) in period 2 writes:

$$\begin{aligned}
\max_{C_{2b},C_{2c},K_2,r_2,M_{2b},M_{2c}} \quad & u(C_{2b}) + (\lambda+\mu)u(C_{2c}) \\
\text{s.t.} \quad & C_{2b} = (1+r_2)((1-\delta)K_1 + I_1) + M_{2b}, \\
& C_{2c} + (1+r_2)K_2 = A_2 K_2^{\alpha} - \mathscr{D}(\sigma A_1 K_1^{\alpha} - E_1) + M_{2c}, \\
& 1 + r_2 = \alpha A_2 K_2^{\alpha-1}, \\
& K_2 = (1-\delta)K_1 + I_1, \\
& M_{2b} + M_{2c} = 0.
\end{aligned} \tag{33}$$

(33) simplifies to the constraints in (33) and:

$$\begin{aligned}
\max_{C_{2b},C_{2c}} \quad & u(C_{2b}) + (\lambda+\mu)u(C_{2c}) \\
\text{s.t.} \quad & C_{2b} + C_{2c} = A_2((1-\delta)K_1 + I_1)^{\alpha} - \mathscr{D}(\sigma A_1 K_1^{\alpha} - E_1).
\end{aligned} \tag{34}$$

By deriving the first order conditions of (34), (33) finally simplifies to the constraints in (33) and:

$$u'(C_{2b}) = (\lambda + \mu)u'(C_{2c}). \tag{35}$$

A.2.2 First period

By denoting $C = (C_{1a}, C_{1b}, C_{2b}, C_{2c})$, $K = (K_1, K_2)$, $r = (r_1, r_2)$, $\tau = (\tau_E, \tau_I)$ and $M = (M_{1a}, M_{1b}, M_{2b}, M_{2c})$, the government's problem (16) in period 1 writes:

$$\begin{aligned}
\max_{C,K,I_1,E_1,r,\tau,M} \quad & u(C_{1a}) + (\lambda+\mu)u(C_{1b}) + (\lambda+\mu)\beta u(C_{2b}) + (\lambda^2+\lambda\mu)\beta u(C_{2c}) \\
\text{s.t.} \quad & C_{2b} = (1+r_2)((1-\delta)K_1 + I_1) + M_{2b}, \\
& C_{2c} + (1+r_2)K_2 = A_2K_2^{\alpha} - \mathscr{D}(\sigma A_1 K_1^{\alpha} - E_1) + M_{2c}, \\
& 1 + r_2 = \alpha A_2 K_2^{\alpha-1}, \\
& K_2 = (1-\delta)K_1 + I_1, \\
& M_{2b} + M_{2c} = 0, \\
& u'(C_{2b}) = (\lambda+\mu)u'(C_{2c}), \\
& C_{1a} = (1+r_1)\overline{K} + M_{1a}, \\
& C_{1b} + (1+r_1)K_1 = A_1K_1^{\alpha} - \mathscr{C}(E_1) - \tau_E(\sigma A_1 K_1^{\alpha} - E_1) - I_1 - \tau_I I_1 + M_{1b}, \\
& u'(C_{1b}) = \beta u'(C_{2b}) \frac{1+r_2}{1+\tau_I}, \\
& \mathscr{C}'(E_1) = \tau_E, \\
& 1 + r_1 = (1-\tau_E\sigma)\alpha A_1 K_1^{\alpha-1} + (1-\delta)(1+\tau_I), \\
& K_1 = \overline{K}, \\
& M_{1a} + M_{1b} - \tau_E(\sigma A_1 K_1^{\alpha} - E_1) - \tau_I I_1 = 0.
\end{aligned} \tag{36}$$

(36) simplifies to the constraints in (36) and:

$$
\begin{aligned}
\max_{C,I_1,E_1,\tau_I} \quad & u(C_{1a})+(\lambda+\mu)u(C_{1b})+(\lambda+\mu)\beta u(C_{2b})+(\lambda^2+\lambda\mu)\beta u(C_{2c}) \\
\text{s.t.} \quad & C_{2b}+C_{2c}=A_2((1-\delta)\overline{K}+I_1)^{\alpha}-\mathscr{D}(\sigma A_1\overline{K}^{\alpha}-E_1), \\
& u'(C_{2b})=(\lambda+\mu)u'(C_{2c}), \\
& C_{1a}+C_{1b}=A_1\overline{K}^{\alpha}-\mathscr{C}(E_1)-I_1, \\
& \tau_I=\beta\frac{u'(C_{2b})}{u'(C_{1b})}\alpha A_2((1-\delta)\overline{K}+I_1)^{\alpha-1}-1.
\end{aligned} \tag{37}
$$

Given (37), (36) further simplifies to the constraints in (36) and:

$$
\begin{aligned}
\max_{C,I_1,E_1} \quad & u(C_{1a})+(\lambda+\mu)u(C_{1b})+(\lambda+\mu)\beta u(C_{2b})+(\lambda^2+\lambda\mu)\beta u(C_{2c}) \\
\text{s.t.} \quad & C_{2b}+C_{2c}=A_2((1-\delta)\overline{K}+I_1)^{\alpha}-\mathscr{D}(\sigma A_1\overline{K}^{\alpha}-E_1), \\
& u'(C_{2b})=(\lambda+\mu)u'(C_{2c}), \\
& C_{1a}+C_{1b}=A_1\overline{K}^{\alpha}-\mathscr{C}(E_1)-I_1.
\end{aligned} \tag{38}
$$

By deriving the first order conditions of (38), (36) then simplifies to the constraints in (36) and:

$$u'(C_{1a})=(\lambda+\mu)u'(C_{1b}), \tag{39}$$

$$u'(C_{1b})=\beta u'(C_{2b})\left[1-\frac{\mu u''(C_{2b})}{u''(C_{2b})+(\lambda+\mu)u''(C_{2c})}\frac{u'(C_{2c})}{u'(C_{2b})}\right]\alpha A_2((1-\delta)\overline{K}+I_1)^{\alpha-1}, \tag{40}$$

$$\mathscr{C}'(E_1)=\beta\left[\frac{u'(C_{2b})}{u'(C_{1b})}-\frac{\mu u''(C_{2b})}{u''(C_{2b})+(\lambda+\mu)u''(C_{2c})}\frac{u'(C_{2c})}{u'(C_{1b})}\right]\mathscr{D}'(\sigma A_1\overline{K}^{\alpha}-E_1). \tag{41}$$

With the constraints in (36), the two latter equations finally give:

$$\tau_I=\frac{\mu u''(C_{2b})}{u''(C_{2b})+(\lambda+\mu)u''(C_{2c})}\frac{1}{\lambda+\mu}, \tag{42}$$

$$\tau_E=\frac{1}{1+r_2}\mathscr{D}'(\sigma A_1\overline{K}^{\alpha}-E_1). \tag{43}$$

A.3 Proof of Proposition 3

With $u(x) = \frac{x^{1-\eta}-1}{1-\eta}$, the Euler equation (10) writes:

$$\frac{1}{1+r_2} = \frac{\beta}{1+\tau_I}\left(\frac{C_{1b}}{C_{2b}}\right)^{\eta}. \tag{44}$$

(35) and (39) simplify to $(\frac{C_{2c}}{C_{2b}})^{\eta} = \lambda+\mu$ and $(\frac{C_{1b}}{C_{1a}})^{\eta} = \lambda+\mu$, respectively, which can be rewritten, respectively:

$$C_{2b} = \frac{C_{2b}+C_{2c}}{1+(\lambda+\mu)^{1/\eta}}, \tag{45}$$

$$C_{1b} = \frac{C_{1a}+C_{1b}}{1+(\lambda+\mu)^{-1/\eta}}. \tag{46}$$

(42) rewrites:

$$\tau_I = \frac{\mu}{1+(\lambda+\mu)\left(\frac{C_{2b}}{C_{2c}}\right)^{1+\eta}}\frac{1}{\lambda+\mu}, \tag{47}$$

which simplifies with $\frac{C_{2b}}{C_{2c}} = \frac{1}{(\lambda+\mu)^{\frac{1}{\eta}}}$ to:

$$\tau_I = \frac{\mu}{\lambda+\mu+(\lambda+\mu)^{\frac{\eta-1}{\eta}}}. \tag{48}$$

With (45), (46) and (48), (44) finally rewrites:

$$\frac{1}{1+r_2} = \beta\frac{1}{\left(\frac{C_{2b}+C_{2c}}{C_{1a}+C_{1b}}\right)^{\eta}}(\lambda+\mu)\frac{1+(\lambda+\mu)^{\frac{1}{\eta}}}{1+(\lambda+\mu)^{\frac{1}{\eta}}+(\lambda+\mu)^{\frac{1-\eta}{\eta}}\mu}. \tag{49}$$

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