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Intergenerational altruism: A solution to the climate problem?*

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Intergenerational altruism:
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Abstract

The future effects of climate change may induce increased intergenerational altruism. But will increased intergenerational altruism reduce the threat of climate change? In this chapter we investigate this question. In a second-best setting with insufficient control of greenhouse gas emissions in the atmosphere, increased transfers to future generations through accumulation of capital might result in additional accumulation of greenhouse gases, and thereby aggravate the climate problem. In contrast, transfers to the future through control of greenhouse gas emissions will alleviate the climate problem. Whether increased intergenerational altruism is a means for achieving accumulation of consumption potential (through accumulation of capital) without increasing the climate threat depends on how it affects factors motivating the accumulation of capital and the control of emissions of greenhouse gases. An argument is provided for why increased intergenerational altruism in fact will aggravate the climate problem. We use the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016) to facilitate the discussion.

Keywords and Phrases: Intergenerational altruism, climate change.

JEL Classification Numbers: D63, D64, Q01, Q54.

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1 Introduction

The emissions of greenhouse gases in the atmosphere threaten future climate stability and might undermine the wellbeing of future generations. It is natural to believe that this threat will enhance the concern that people have for their descendants and, thus, strengthen intergenerational altruism. The question that we pose in the present chapter is: Will the increased transfers that such strengthened intergenerational altruism leads to be a blessing for future generations by alleviating the climate problem, or will it aggravate the climate problem?

In a world where the public good problem of controlling the emissions of greenhouse gases is solved by collective action, the possible negative climate externalities of capital accumulation motivated by transfers of consumption potential to future generations will also be internalized. Hence, the dilemma we pose—namely, that the increased intergenerational transfers motivated by the threat of climate change will themselves contribute to increase this threat—only arises if such collective action has not been put in place. So in other words, we ask whether strengthened intergenerational altruism can function as an endogenously emerging second-best substitute if no first-best collective climate action will be undertaken.[1]

We will discuss this dilemma in the context of an intergenerational game played by dynasties. The currently living decision-maker of a dynasty makes choices as to maximize a weighted sum of own utility (of consumption and the stock of greenhouse gases) and the utilities of descendants of the same dynasty, with intergenerational altruism being measured by the weight assigned to the utilities of descendants. The strength of such intergenerational altruism is related to the pure time preference term in the Ramsey rule, so that a relative weight on the utilities of descendants approaching one corresponds to a rate of pure time preference approaching zero.[2]

In this game, factors that motivate the accumulation of capital (and thereby the growth of consumption potential) are the concern for lifetime utility and the weight

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[1] An alternative motivation for the chapter is the following: Discounting the long-term future has received much attention, most prominently in Nordhaus' discussion of the Stern Review (Nordhaus, 2007; Stern, 2007). As a consequence of the adoption of a low discount rate, the Stern Review effectively advocated for stringent action on climate change. In a second-best setting, however, reducing the discount rate may lower rather than increase welfare due to the public good problem. This point is usually overlooked in the debate on discounting which unrealistically operates in a first-best setting.

[2] It is not related to the other source of a positive consumption discount rate according to the Ramsey rule, namely aversion to inequality/fluctuation under consumption growth.

assigned to the utilities of descendants. The higher the concern for lifetime utility and the heavier the weight assigned to the utilities of descendants, the greater is the motivation for accumulating capital for the purpose of enhancing growth of consumption potential.

Factors that motivate individual control of emissions of greenhouse gases in the atmosphere, provided that dynasties are of positive measure (i.e., that they are able to influence aggregates), are also the concern for lifetime utility and the weight assigned to the utilities of descendants. The higher the concern for lifetime utility and the heavier the weight assigned to the utilities of descendants, the greater is the motivation for individual control of emissions of greenhouse gases. However, due to the public good nature of controlling greenhouse gas emissions, these motivating factors might well be quite weak.

Increased intergenerational altruism increases the weight on the utilities of descendants. We evaluate the desirability of such altruism by the extent to which it facilitates intergenerational transfer without increasing the climate threat: Is increased intergenerational altruism a means for achieving accumulation of consumption potential without accumulation of greenhouse gases? If this is the case, increased intergenerational altruism solves the distributional problem posed by future climate change while alleviating (or at least, without aggravating) the efficiency problem.

We review the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016), which should be considered as examples of contributions to the literature.[3] These models are similar in terms of inefficiencies but different in terms of the considered factors motivating the accumulation of capital and the control of greenhouse gas emissions.

Jouvet et al. (2000) consider a simplified overlapping generations model, with lifetime equal to two periods (young and old), in which there is no consumption as young.

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[3] There are other contributions to this literature that might be relevant. In an early contribution Howarth and Norgaard (1995) made the point that there might be a need for collective action since altruistic agents do not necessarily fully internalize externalities. Rezai et al. (2012) use a non-overlapping generations model which in theory is equivalent to an overlapping generations model with perfect bequest motives. They show that a reduction in the discount rate could lead to accumulation of capital and greenhouse gases in a setting where the public good problem in the control of the emissions of greenhouse gases is severe. While the focus in this chapter is on climate externalities of capital accumulation, there are also other approaches taken in the literature. John and Pecchenino (1994), for example, focus in an overlapping generations model on effects of externalities through consumption. We refer the readers to Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016) for an overview of other relevant contributions.

Karp (forthcoming) considers an overlapping generations model, with expected life time constant. Asheim and Nesje (2016) consider a non-overlapping generation model, with lifetime equal to one period. Dynasties are of positive measure in both Jouvet et al. (2000) and Karp (forthcoming) and of zero measure in Asheim and Nesje (2016).

Both Jouvet et al. (2000) and Asheim and Nesje (2016) include motives for the accumulation of capital. In Jouvet et al. (2000) the motive is due to the concern for utility as old and the welfare of the immediate descendants (which is an aggregate of the utilities of all future descendants). In Asheim and Nesje (2016) it is due to the concern for the welfare of the immediate descendants (which is an aggregate of the utilities of all future descendants). Karp (forthcoming) does not include motives for capital accumulation as the accumulation of capital is exogenous.

Jouvet et al. (2000) and Karp (forthcoming) include motives for control of emissions of greenhouse gases in the atmosphere. In Jouvet et al. (2000) the motive is due to the same factors as above, subject to the limitation imposed by the public good nature of such control. In Karp (forthcoming) it is there due the concern for lifetime utility and the utility of descendants, subject to the same limitation. Asheim and Nesje (2016) do not include motives for control of emissions of greenhouse gases in the atmosphere, since each dynasty is of zero weight and therefore cannot influence aggregates.

Jouvet et al. (2000) is the only paper with factors motivating both the accumulation of capital and control of emissions of greenhouse gases in the atmosphere. However, there seems to be an inconsistency in how they define the equilibrium of the intergenerational game played by dynasties.[4] As a consequence, we study the accumulation of capital and the control of greenhouse gas emissions separately.

In reviewing the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016), we find that transfers to future generations through accumulation of capital might aggravate the climate problem in a second-best setting with insufficient control of greenhouse gas emissions in the atmosphere. In contrast, transfers to the future through control of greenhouse gas emissions will alleviate this problem. Whether increased intergenerational altruism is a means for achieving accumulation of consumption potential without accumulation of greenhouse gases depends on how it affects factors motivating the accumulation of capital and control of greenhouse gas emissions. An argument is provided for why increased intergenerational transfers motivated by the future effects of climate change in fact will increase the threat.

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[4] While dynasties in Jouvet et al. (2000) are of positive weight in the control of greenhouse gas emissions game, they are of zero weight in the capital accumulation game.

The plan of the chapter is as follows. Section 2 informally presents the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016) and clarifies some key concepts. Section 3 discusses factors that motivate the accumulation of capital (and thereby the growth of consumption potential) and the control of greenhouse gas emissions, and asks to what extent increased intergenerational altruism is a solution to the climate problem. Section 4 discusses increased cooperation between dynasties as an alternative solution to the climate problem. Section 5 provides concluding remarks.

The appendix gives a formal presentation of the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016) and the results.

2 Informal presentation of models

The purpose of this section is to informally present the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016), which should be viewed as examples of contributions to the literature, and to clarify some key concepts. A formal presentation of these models is given in the appendix. We use the models to facilitate the discussion in Section 3 on whether increased intergenerational altruism is a means for achieving accumulation of consumption potential without accumulation of greenhouse gases in the atmosphere, and thereby is at least a solution to the distributional problem that the threat of climate change poses.

Jouvet et al. (2000)

Consider a discrete time infinite horizon economy consisting of a finite number of dynasties. Dynasties are interpreted as households of constant population. The structure is a simplified overlapping generations model, with lifetime equal to two periods (young and old), in which there is no consumption as young. What is left of the overlapping generations structure is thus that there is a need for capital accumulation (and capital holdings) in order to transfer wage income earned as young to consumption as old.

As young, a member of a dynasty earns wage income by supplying one unit of labor (exogenously) and receives bequest from the currently living old member. This is all saved for old age. As old, the member allocates its savings between consumption, capital accumulation for bequest and control of greenhouse gas emissions. The member derives utility from consumption and disutility from the stock of greenhouse gases as old. The utility function is strictly concave, with the cross-derivative non-positive.

The currently living old member of a dynasty makes choices as to maximize own welfare, which is a weighted sum of own utility and the welfare of the immediate descendants. Here, intergenerational altruism is non-paternalistic since it takes into account that descendants might care about their descendants. It is of first order since it considers directly immediate descendants only.

The production is a constant-returns-to-scale function of the inputs labor and capital. Thus, output equals units of labor multiplied with a per capita production function, with the capital-labor ratio as argument. The production function is positive, increasing, and strictly concave. Capital fully depreciates after one period. The wage equals the marginal product of labor. Output level and the return on capital are assumed not to be affected by the actions of a single dynasty.[5]

The dynamics of the stock of greenhouse gases depend positively linearly on output level in the current period and the stock of greenhouse gases in the previous period and negatively linearly on the control of greenhouse gas emissions.[6] The dependence of the stock on the control of greenhouse gas emissions can be separated into two additive components, with the first representing the control of a single dynasty and the second representing the aggregate control of all other dynasties.

The equilibrium considered is a symmetric Nash equilibrium. We focus on the case in which capital is accumulated for bequest and there at least is some control of greenhouse gas emissions. Each dynasty can invest either in capital or control of greenhouse gas emissions. Since each dynasty is of positive weight in the control of greenhouse gas emissions game, it is individually rational to invest in some control of greenhouse gas emissions in addition to capital. The equilibrium is solved for by letting the initial member of a dynasty choose its path of capital and control taking as given the corresponding actions by the other dynasties. As a result of the the failure to internalize the climate externality of capital accumulation and a public good problem in the control of greenhouse gas emissions, the equilibrium is inefficient.

Due to the inconsistency in the definition of the equilibrium, where dynasties are assumed to be of positive weight in the control of greenhouse gas emissions game and of zero weight in the capital accumulation game, we assess factors motivating accumulation of capital and control of greenhouse gas emissions in separate.

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[5] Note that this is inconsistent with the assumption of a finite number of dynasties.

[6] While the current stock is a positive function of the stock in the previous period, the change of the stock from the previous period to the current one is a negative function of the stock in the previous period.

Karp (forthcoming)

Consider a continuous time infinite horizon economy consisting of a finite number of dynasties. Here, dynasties are interpreted as same-size countries of constant population. The structure is an overlapping generations model, with expected life time and mortality rate constant and, thus, birth rate constant. Since currently living members have identical utility functions and expected life time is constant, they are identical.

In this model, accumulation of capital is exogenous (and, thus, taken as given), while the control of greenhouse gas emissions is endogenous. The change in the stock of greenhouse gases is assumed to depend positively on aggregate emissions and negatively linearly on the stock of greenhouse gases.

The utility of a member of a dynasty equals its stream of utility flows, discounted by the impatience for own utility and risk-adjusted by the mortality rate. The utility flow depends positively linearly on the logarithm of consumption and negatively linearly on the stock of greenhouse gases.[7] Consumption is Cobb Douglas in emissions of greenhouse gases, with technology level exogenous. This means that if a dynasty increases its control of greenhouse gas emissions (by reducing its own emissions, and thereby own consumption), it is effectively also increasing the utility of all current and future members of all dynasties.

A representative of the currently living (identical) members of a dynasty, constrained to sharing costs associated with the control of greenhouse gas emissions equally among currently living members, makes choices as to maximize own welfare, which is a weighted sum of own utility and the utilities of descendants. Intergenerational altruism is paternalistic since it does not take into account that descendants might care about their descendants. It is of higher order since it considers directly not only on immediate descendants.

The equilibria considered are stationary symmetric Markov Perfect equilibria (MPE). Here, the action of the currently living representative of a dynasty, which is control of greenhouse gas emissions, depends only on the stock of greenhouse gases. The representatives of each dynasty can invest in control of greenhouse gas emissions. Since each dynasty is of positive weight, it is individually rational to invest in some control of greenhouse gas emissions. An equilibrium is solved for by specifying a decision rule that is a best response if and only if it is used by all other representatives, including future representatives of the same dynasty. As a result of a public good problem in the

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[7] This is a bit imprecise since it is the representation of the utility flow in equilibrium.

control of greenhouse gas emissions, equilibria are inefficient.

Asheim and Nesje (2016)

Consider a discrete time infinite horizon economy consisting of an uncountably infinite (a continuum) number of dynasties, which, in contrast to Karp (forthcoming), implies that no single dynasty is able to influence aggregates. Dynasties are interpreted as families or tribes of constant population. The structure is a non-overlapping generation model, with lifetime equal to one period. This model therefore does not have concern-for-lifetime-utility motives for accumulation of capital.

Production is a constant-returns-to-scale function using inputs labor and capital. The per capita production function, with the capital-labor ratio as argument, is increasing, and strictly concave. Labor, which is uniformly distributed over dynasties and sum to one, is supplied exogenously.

In this economy there are two types of capital: polluting and non-polluting capital. The productivity of non-polluting capital is a fraction less than one of the productivity of polluting capital. Consumption potential can therefore be accumulated without accumulation of greenhouse gases if only the non-polluting capital is used. This can even be efficient if the reduction in the consumption potential by substitution from polluting to non-polluting capital (due to the lower productivity) is offset by the reduction in pollution that this leads to.

The utility of a member of a dynasty depends positively on consumption, but is adjusted downwards by the stock of greenhouse gases in the atmosphere (as proxied by the aggregate stock of polluting capital). The utility function is increasing, and strictly concave in consumption, while the stock of greenhouse gases adjusts utility downwards in a multiplicative way though a continuous and decreasing adjustment function.

The currently living member of a dynasty maximizes own welfare, which is a weighted sum of own utility and the welfare of the immediate descendants. As in Jouvet et al. (2000) intergenerational altruism is non-paternalistic and of first order.

The equilibrium considered is a symmetric Nash equilibrium. Each dynasty can invest either in polluting or non-polluting capital. Since each dynasty is of zero weight, it is individually rational to invest only in polluting capital since this relaxes its budget constraint without affecting the aggregate stock of polluting capital that adjusts utility for all dynasties downwards. The equilibrium is solved for by letting the initial member of a representative dynasty choose its path of polluting capital taking as given the aggregate path. As a result of the failure to internalize the climate externality of capital accumulation, the equilibrium is inefficient.

3 Intergenerational altruism as a solution?

The purpose of this section is to ask whether increased intergenerational altruism is a solution to at least the distributional problem that future climate change poses and to relate the discussion to the properties of the models as presented in Section 2.

To prepare the discussion we first summarize for each model the factors that motivate the accumulation of capital and control of greenhouse gas emissions. Then, we clarify model-by-model whether increased intergenerational altruism can be a solution. A formal presentation of results is given in the appendix. The section is concluded by an argument against the case for increased intergenerational altruism as a second-best substitute if no first-best collective action is undertaken to control of greenhouse gas emissions.

The motivating factors

The factors motivating the accumulation of capital and control of greenhouse gas emissions are summarized in Panel A of Table 1.

The concern for lifetime utility and the weight assigned to the utilities of descendants are factors that motivate the accumulation of capital. The concern-for-lifetime-utility motive is included in Jouvet et al. (2000) since there is no consumption as young, while the concern-for-the-utilities-of-descendants motive is included in Jouvet et al. (2000) and Asheim and Nesje (2016). There are no motives for the accumulation of capital in Karp (forthcoming) since the accumulation of capital is exogenous.

Provided that dynasties are of positive measure (i.e., that they are able to influence aggregates), the concern for lifetime utility and the weight assigned to the utilities of descendants are also factors that motivate the control of greenhouse gas emissions in the atmosphere. Both the concern-for-lifetime-utility and the concern-for-the-utilities-of-descendants motives are included in Jouvet et al. (2000) and Karp (forthcoming). The concern-for-lifetime-utility motive is included since members care about the stock of greenhouse gases later in life. There are no motives for avoiding accumulation of greenhouse gases in Asheim and Nesje (2016) since dynasties are of zero measure.

Table 1: An overview of the considered models

		Jouvet et al.	Karp	Asheim and Nesje
A. The motivating factors				
Accumulation of capital	Lifetime utility	Yes	No	No
	Intergen. altruism	Yes	No	Yes
Contr. of greenh. gas emissions	Lifetime utility	Yes	Yes	No
	Intergen. altruism	Yes	Yes	No
B. Results on incr. intergen. altruism				
Solution to the distributional problem?		It depends	Yes	No
Solution to the efficiency problem?		It depends	Yes	No

Results on increased intergenerational altruism

Increased intergenerational altruism motivated by the future effects of climate change increases the weight on the utilities of descendants in the objective of the currently living decision-maker of a dynasty. The results on whether increased intergenerational altruism is a solution to the distributional problem posed by future climate change while alleviating the efficiency problem are summarized in Panel B of Table 1.

Jouvet et al. (2000). In this model intergenerational altruism affects both the motives for the accumulation of capital for bequest as well as the control of greenhouse gas emissions. Since this is an overlapping generations model and utility depends on consumption and the stock of greenhouse gases while old, this comes on top of the concern-for-lifetime-utility motives for accumulation of capital and the control of greenhouse gas emissions. Increased intergenerational transfers thus takes the form of both bequest and control of greenhouse gas emissions. In effect, consumption potential is accumulated while the effect on accumulation of greenhouse gases is unclear.

If the level of intergenerational altruism is sufficiently low, then capital accumulation, keeping everything else constant, results in decreased greenhouse gas accumulation. Capital accumulation makes available more resources to abate greenhouse gas emissions. The resulting emissions reduction of this effort is larger than the emissions increase due to capital accumulation. If the level of intergenerational altruism is sufficiently high, then capital accumulation, keeping everything else constant, results in increased greenhouse gas accumulation. The reduced emissions resulting from increased effort in greenhouse gas abatement made available by capital accumulation is smaller than the increased emissions due to capital accumulation. Control of greenhouse gas emissions therefore increases. The total effect on the accumulation of greenhouse gases, however, is not investigated in the paper.

In this model increased intergenerational altruism therefore does not necessarily solve the distributional problem of future climate change. Since the climate problem can be aggravated, increased intergenerational altruism is not necessarily desirable.

Karp (forthcoming). In this model intergenerational altruism affects the motive for control of greenhouse gas emissions. This comes on top of the concern-for-lifetime-utility motive, since it is an overlapping generations model where the utility flow depends on consumption and the stock of greenhouse gases at later points in life. Increased intergenerational transfers thus takes the form of control of greenhouse gas emissions.

In effect, accumulation of greenhouse gases is reduced while capital accumulation is exogenous and thus unaffected. Increased intergenerational altruism can therefore be a solution to the distributional problem posed by future climate change.

Increased intergenerational altruism decreases the steady state value of the stock of greenhouse gases and can in fact lead to a steady state near the steady state that would have been chosen by an infinitely patient social planner. As intergenerational altruism goes toward its upper level, the efficiency problem thus implodes. Since the climate problem is reduced, increased intergenerational altruism is desirable.

Asheim and Nesje (2016). In this model intergenerational altruism affects the motive for the accumulation of (polluting) capital. Since it is a non-overlapping generations model, there are no concern-for-lifetime-utility motives. Increased intergenerational transfers thus takes the form of bequest only. In effect, both consumption potential and greenhouse gases are accumulated. Increased intergenerational altruism therefore does not solve the distributional problem posed by future climate change.

Increased intergenerational altruism increases the steady state value of polluting capital but can lead to a steady state very far from the steady state that would have been chosen by a social planner. As intergenerational altruism goes toward its upper level, the efficiency problem thus explodes. Since the climate problem is increased, increased intergenerational altruism is not desirable.

To summarize, in a second-best setting with insufficient control of greenhouse gas emissions in the atmosphere, transfers to future generations through accumulation of capital might result in accumulation of greenhouse gases, and thereby aggravate the climate problem. In contrast, transfers to the future through control of greenhouse gas emissions will alleviate the climate problem.

Whether increased intergenerational altruism is a means for achieving accumulation of consumption potential without accumulation of greenhouse gases, and thereby is at least a solution to the distributional problem that the effect of climate change poses, depends on how it affects factors motivating the accumulation of capital and the control of greenhouse gas emissions. If increased intergenerational altruism motivates a sufficiently stricter control of greenhouse gas emissions as compared to the enhanced accumulation of capital, then it might be a solution to the distributional problem posed by future climate change—while even alleviating the efficiency problem—since consumption potential can be accumulated without the accumulation of greenhouse gases.

Jouvet et al. (2000) and Asheim and Nesje (2016) include a concern-for-the-utilities-of-descendants motive for the accumulation of capital. However, due to the public good problem in the control of greenhouse gas emissions, climate externalities of capital accumulation will necessarily not be fully internalized. This implies that accumulation of greenhouse gases, as a result of additional capital accumulation, is increasing in intergenerational altruism.

Since it is natural to think of dynasties—which are interpreted as households in Jouvet et al. (2000), same-size countries in Karp (forthcoming), and families or tribes in Asheim and Nesje (2016)—as small relative to the economy at large, the public good problem might in fact be severe. The concern-for-the-utilities-of-descendants motive for the control of greenhouse gas emissions, which is present in Jouvet et al. (2000) and Karp (forthcoming), may therefore be weak, compared to the motive for the accumulation of capital, even if it is the case that intergenerational altruism is high.

Both consumption potential and greenhouse gases will then be accumulated at a higher rate as intergenerational transfers increase. Thus, increased intergenerational altruism will not be a solution to the climate problem.

4 Other solutions?

The purpose of this section is to clarify whether increased cooperation between dynasties is a solution to the climate problem. This discussion is based on the presentation of the models in Section 2, supported by the results presented in the appendix.

Jouvet et al. (2000) and Asheim and Nesje (2016) do not specifically address the issue of increased but partial cooperation, but rather conditions under which full cooperation can be optimal. In Jouvet et al. (2000) the social planner accumulates less capital and has a higher willingness to pay for control of greenhouse gas emissions. The equilibrium under full cooperation is a symmetric Nash equilibrium, as before, but where capital accumulation for bequest is taxed and control of greenhouse gas emissions is subsidized at appropriate rates. Full cooperation (compared to the case with no cooperation) reduces the motivation for accumulation of capital and increases the motivation for control of greenhouse gas emissions. Asheim and Nesje (2016) consider conditions under which full cooperation can be implemented by requiring that dynasties accumulate non-polluting capital only, and find that this holds if there is a sufficiently small productivity difference between polluting and non-polluting capital.

The constrained optimum can be interpreted as a symmetric Nash equilibrium where each dynasty can invest in non-polluting but not polluting capital. The motivation for avoiding greenhouse gas accumulation is thus increased. For both models this result comes about because the climate externality of capital accumulation is fully internalized when the public good problem in the control of greenhouse gas emissions is solved. Unsurprisingly, full cooperation is a solution to the efficiency problem that future climate change poses since the first-best is obtained.

Karp (forthcoming), on the other hand, also addresses the issue of increased but partial cooperation. Here, the equilibria considered are stationary symmetric MPE, as already defined. Since the number of dynasties can be interpreted as the fragmentation of society into same-size countries of constant population, increased cooperation can be modeled as a reduction in the number of dynasties. Increased cooperation increases the motivation for the control of greenhouse gas emissions because the public good problem becomes less severe. Since cooperation is a means for reducing the accumulation of greenhouse gases without changing the accumulation of consumption potential, it is a solution to the distributional problem imposed by future climate change. Increased cooperation is also a solution to the efficiency problem since the climate problem implodes as cooperation becomes full.

To summarize, increased cooperation between dynasties can be considered a solution to the climate problem.

5 Concluding remarks

In this chapter we have argued that increased intergenerational altruism may not function as a second-best substitute in a world threatened by climate change if no first-best collective action is undertaken to control greenhouse gas emissions. In the context of an intergenerational game played by dynasties, the insight is that since dynasties are so small compared to the aggregate economy, the public good problem in the control of greenhouse gases might still be severe. Thus, consumption potential is not likely to be accumulated (through the accumulation of capital) without increasing the climate threat.

Appendix: Formal presentation of models and results

The purpose of the appendix is to formally present the models of Jouvet et al. (2000), Karp (forthcoming) and Asheim and Nesje (2016) and the results discussed in the chapter.

Jouvet et al. (2000)

The case where capital is accumulated for bequest and there is at least some control of greenhouse gas emissions is studied.

At each time t a new generation of $N > 1$ identical members are born into dynasties. They live for two periods.

There are constant-returns-to-scale using inputs L and K: $Y_t = L_t f(k_t)$, with $k_t = K_t/L_t$. f is twice continuously differentiable, positive, increasing, strictly concave and satisfies the Inada conditions. Capital fully depreciates. The factor prices are given by: $w_t = f(k_t) - k_t f'(k_t)$ and $R_t = f'(k_t)$.

Emissions of greenhouse gases at time t is a function of output level, mY_t, with $m > 0$. Let X_t denote the total amount of resources used to control of greenhouse gas emissions. qX_t is the amount abated in period t, with $q > m$. The stock of greenhouse gases depreciates with rate $h \in (0, 1]$. The dynamics of the stock is $S_t = mY_t + (1-h)S_{t-1} - qX_t$. For the decision-maker of dynasty i at time t, the dynamics are $S_t = mY_t + (1-h)S_{t-1} - q\bar{X}_t - qx_{it}$, with $\bar{X}_t = X_t - x_{it}$.

Preferences of a member born at time t are represented by the utility function $u(c_{t+1}, S_{t+1})$, where c is consumption. $u_c > 0$, $u_S < 0$, $u_{cc} < 0$, $u_{SS} < 0$, and $u_{cS} \leq 0$ and sufficiently small. Welfare can be expressed in the following manner:

$$\sum_{\tau=t}^{\infty} \alpha^{\tau-t} u(c_{\tau+1}, S_{\tau+1}),$$

with $\alpha \in [0, 1)$ denoting intergenerational altruism. Young members supply one unit of labor, earning w_t, inherit z_t and save $s_t = w_t + z_t$. Old members allocate their savings between bequest z_{t+1}, abatement x_{t+1} and consumption $c_{t+1} = R_{t+1}s_t - z_{t+1} - x_{t+1}$.

The symmetric Nash equilibrium is considered. The member of a dynasty born at time t takes as given the actions of other dynasties and chooses c_{t+1}, z_{t+1} and x_{t+1} to maximize own welfare subject to the budget constraints, non-negativity constraints on bequest and abatement, and the dynamics of the stock of greenhouse gases. In equilibrium we have $k_{t+1} = s_t$. Due to symmetry, $X_{t+1} = Nx_{t+1}$.

Assume no bequest and that there exists a unique steady state k^d. We assume that $\alpha > 1/f'(k^d) \equiv \alpha^w$, so that capital will be accumulated for bequest. Define the corresponding steady state $k^\alpha \equiv f'^{-1}(1/\alpha)$. The threshold $\bar{S}^\alpha$, below which no control of greenhouse gas emissions occurs, is defined as the stock of greenhouse gases in the case of capital accumulation for bequest, S^α, that is the solution to

$$0 = u_c(c^\alpha, S^\alpha) + \frac{qu_S(c^\alpha, S^\alpha)}{1-\alpha(1-h)},$$

with $c^\alpha = f(k^\alpha) - k^\alpha$. In the paper it is proved that $\bar{S}^\alpha$ is decreasing in α.

In the paper it is verified that

$$\frac{dk}{d\alpha} > 0.$$

The change in the stock of greenhouse gases can be described in the following manner: $dS = qNh^{-1}(dc + (1-(1-m/q)\alpha^{-1})dk)$. Interpret $1-m/q$ as the rate of control of greenhouse gas emissions. If $\alpha < 1-m/q$, accumulating capital, keeping everything else constant, reduces the stock of greenhouse gases. If $\alpha \geq 1-m/q$, accumulating capital, keeping everything else constant, increases the stock of greenhouse gases.

The following result is proved in the paper:

Proposition 1 *Assume $\alpha > \alpha^w$ and $S^\alpha > \bar{S}^\alpha$. Consumption decreases with the level of intergenerational altruism if $\alpha \geq 1-m/q$. If $\alpha < 1-m/q$ and $h < 1$, the effects of an increase in the level of intergenerational altruism on consumption is indeterminate.*

Since consumption decreases in the case with $\alpha \geq 1-m/q$ and more resources are made available due to capital accumulation, control of greenhouse gas emissions increases. The total effect on the accumulation of greenhouse gases is not investigated in the paper.

Assume that the private and the social discount factors are equal. Consider the following problem of the social planner, which, if decentralized, could be interpreted as the case with cooperation between dynasties:

$$\max_{\{c_t,x_t,P_t,k_{t+1}\}_{t=0}^\infty} \sum_{t=0}^\infty \alpha^t u(c_t, S_t)$$

subject to

$$f(k_t) = c_t + x_t + k_{t+1};\ S_t = mNf(k_t) + (1-h)S_{t-1} - qNx_t;$$
$$x_t \geq 0;\ k_0, S_{-1} \text{ given.}$$

In the paper it is shown that the social planner accumulates less capital and has a higher willingness to pay for control of greenhouse gas emissions. The social planner solution can be decentralized using two instruments.

Karp (forthcoming)

This paper studies a linear-in-state model, where the consumption function is a simplified version of that proposed by Golosov et al. (2014). We limit our presentation to the case of the stationary symmetric non-limit Markov Perfect equilibria (MPE).

There is a finite number of $N \geq 1$ dynasties, where N represents fragmentation of society. Members of dynasties have life time exponentially distributed. The mortality rate is $\theta > 0$. The pure rate of time preference is $r > 0$. Intergenerational altruism can be expressed as $\alpha = 1/(1+\lambda)$, with $\lambda \leq r$ being the rate of discount of descendants' utilities.

Denote by S_t the stock of greenhouse gases in the atmosphere at time t (which is the state variable), and by x_{it} the greenhouse gas emissions at time t by dynasty i. In the symmetric case, $X_t = N x_{it}$. The state variable evolves according to

$$\frac{dS}{dt} = BS + X,$$

with $B < 0$.

As N represents fragmentation, the aggregate can be represented by $N = 1$. Let the aggregate utility flow be $u(X_t, S_t; 1) = \ln\, C(X_t; 1) - \kappa S_t$, where κS_t is loss in consumption due to climate damage. Aggregate consumption is $C(X_t; 1) = A_t X_t^{\eta}$, with technology level A_t exogenous. Due to symmetry, the flow utility for dynasty i at time t is $u(x_{it}, S_t; N) = (\ln A_t/N) + (\eta/N)\ln x_{it} - (\kappa/N)S_t$.

Denote $U_{it} = \int_{\tau=t}^{\infty} e^{-(r+\theta)(\tau-t)} u(x_{i\tau}, S_\tau; N) d\tau$. Welfare can then be expressed as

$$U_{it} + \theta \int_{\tau=t}^{\infty} e^{-\lambda(\tau-t)} U_{i\tau} d\tau = \int_{\tau=t}^{\infty} D(\tau-t) u(x_{i\tau}, S_\tau; N) d\tau,$$

with $D(\tau - t)$ defined according to

$$D(t) = \frac{\lambda - r}{\lambda - (r+\theta)} e^{-(r+\theta)t} - \frac{\theta}{\lambda - (r+\theta)} e^{-\lambda t}.$$

At each point in time t currently living (identical) members of a dynasty are represented by a representative who shares the chosen cost of control of greenhouse gas emissions equally among the members. Representatives' control depend only on S_t. $\chi(S)$ is an MPE if and only if $x_{it} = \chi(S_t)$ is the best response, for all feasible S, for representatives i, t when all other representatives use this decision rule.

It is shown in the paper that η/κ is the steady state chosen by a social planner with $\alpha = 1$. This steady state is the Green Golden Rule (GGR). It is also verified that there exists an MPE close to the GGR.

Let Φ be the derivative of aggregate emissions with respect to the stock of greenhouse gases at the steady state. Define Υ as the steady state stock given by Φ, as a share of GGR.

The following result is proved in the paper:

Proposition 2 *For any* $0 \leq \Phi < -B$*, increased cooperation or intergenerational altruism (smaller* N *or larger* α*) move the MPE steady state closer to GGR:* $\frac{d\Upsilon}{dN} > 0$*,* $\frac{d\Upsilon}{d\alpha} < 0$*. For all values of* N*, there exists an MPE steady state arbitrarily close to the GGR for* α *close to* 1*. This steady state is supported by a decision rule corresponding to* Φ *close to its upper bound (*$\Phi = -B$*). In contrast, even for full cooperation (*$N = 1$*), the steady state is bounded away from the GGR for* α *bounded away from* 1*.*

Asheim and Nesje (2016)

There is an uncountably infinite number (a continuum) of dynasties, consisting of altruistically linked members each living for one time period.

Production is a constant-returns-to-scale function of capital and labor, so that the per capita production function, f, satisfies the Inada conditions with the additional assumption that per capita consumption is bounded above.

There are two kinds of capital, polluting and non-polluting capital. A consumption stream ${}_1c = (c_1, c_2, \dots) \geq 0$ is feasible given a pair of initial capital stocks $(b, g) > 0$ if there exist streams of polluting capital ${}_0b = (b_0, b_1, b_2 \dots) \geq 0$ and non-polluting capital ${}_0g = (g_0, g_1, g_2 \dots) \geq 0$ such that $(b_0, g_0) = (b, g)$ and

$$c_t + b_t + g_t = b_{t-1} + g_{t-1} + f(b_{t-1} + (1-\gamma)g_{t-1}) \tag{1}$$

for all $t \in \mathbb{N}$, where $\gamma \in (0, 1)$ measures to what extent non-polluting capital is less productive.

Labor is uniformly distributed over a continuum of dynasties i on the unit interval $[0, 1]$. Assume that the map from consumption to utility for dynasty i in generation

t, in addition to depending on an increasing, strictly concave, and continuously differentiable utility function $u : \mathbb{R}_+ \to \mathbb{R}$, satisfying $u(0) = 0$ and $\lim_{c\to 0} u'(c) = \infty$, also depends on the aggregate amount of polluting capital accumulated by generation $t-1$: $a(b_{t-1})u(\mathbf{c}_t(i))$, where the continuous and decreasing function $a : \mathbb{R}_+ \to \mathbb{R}$, satisfying $a(0) = 1$ and $\lim_{b\to\infty} a(b) = 0$, captures the effect of the climate externalities caused by polluting capital, and where $\mathbf{c}_t(i)$ is the consumption of dynasty i. Refer to $u_t = a(b_{t-1})u(\mathbf{c}_t(i))$ as adjusted utility.

Dynasties have the same u function, they are affected in the same manner by the adjustment, and they have same non-paternalistic altruistic (NPA) welfare function:

$$(1-\alpha)\sum\nolimits_{t=0}^{\infty}\alpha^t a(b_t)u(\mathbf{c}_{t+1}(i)),$$

where $\alpha \in (0,1)$ is the per generation factor used to discount future utilities. Each dynasty i can invest in either polluting $\mathbf{b}_t(i)$ or non-polluting $\mathbf{g}_t(i)$ capital. Since each dynasty is of zero weight, it is individually rational for each dynasty to invest in polluting capital only, as this relaxes its budget constraint (1), while not influencing the aggregate stock of polluting capital that adjusts its utility. If the profile of initial ownership to capital is assumed to be uniform, the dynasties will behave in the same manner. This implies that each dynasty i, for all $t \in \mathbb{N}$, chooses $\mathbf{b}_t(i) = b_t$ and $\mathbf{g}_t(i) = 0$ so that the budget constraint (1) is satisfied.

Since u is strictly concave, the analysis can be performed by considering a representative dynasty. The analysis is simplified by considering the case where the initial stock of non-polluting capital, g, is zero, so that only the initial stock of polluting capital, b, is positive. Under this assumption and taking into account that dynasties will choose to accumulate only polluting capital, the set of (polluting) capital streams as a function of the initial stock is $K(b) = \{{}_0b : b_0 = b \text{ and } 0 \le b_t \le b_{t-1} + f(b_{t-1}) \text{ for all } t \in \mathbb{N}\}$. Write $\mathcal{K} = \bigcup_{b\in\mathbb{R}_+} K(b)$. Define $\mathbf{c}({}_0b) = (b_0 + f(b_0) - b_1, b_1 + f(b_1) - b_2, \ldots, b_{t-1} + f(b_{t-1}) - b_t, \ldots)$ as the consumption stream that is associated with ${}_0b$. Consumption streams as a function of the initial stock is $C(b) = \{{}_1c : \text{there is } {}_0b \in K(b) \text{ s.t. } {}_1c = \mathbf{c}({}_0b)\}$. Say that ${}_1c \in C(b)$ is efficient if there is no ${}_1\tilde{c} \in C(b)$ such that ${}_1\tilde{c} > {}_1c$.

The symmetric Nash equilibrium is considered. The representative dynasty maximizes the NPA welfare function over all consumption streams ${}_1c \in C(b)$ while taking the climate externalities caused by the stream of brown capital, ${}_0b \in K(b)$, as given. The NPA welfare function $v_\alpha : \mathcal{K} \times \mathcal{K}$ defined over capital streams is given by:

$$v_\alpha({}_0k, {}_0b) = (1-\alpha)\sum\nolimits_{t=0}^{\infty}\alpha^t a(b_t)u(k_t + f(k_t) - k_{t+1}),$$

with $\alpha \in (0,1)$, where $k_0 = b$ and k_t is polluting capital held by the representative dynasty for $t \in \mathbb{N}$. The representative dynasty takes ${}_0b$ as given when maximizing $v_\alpha({}_0k, {}_0b)$ over all ${}_0k \in K(b)$. However, in equilibrium, ${}_0k = {}_0b$, leading to the following definition: ${}_0b \in K(b)$ is a NPA equilibrium if

$$v_\alpha({}_0b, {}_0b) \geq v_\alpha({}_0\tilde{k}, {}_0b) \quad \text{for all } {}_0\tilde{k} \in K(b)\,.$$

Define $k_\infty : (0,1) \to \mathbb{R}_+$ by, for all $\alpha \in (0,1)$, $\alpha\,(1 + f'(k_\infty(\alpha))) = 1$. It follows from the properties of f that k_∞ is well-defined, continuous, and increasing, with $\lim_{\alpha \to 0} k_\infty(\alpha) = 0$ and $\lim_{\alpha \to 1} k_\infty(\alpha) = \infty$. For given $\alpha \in (0,1)$, $k_\infty(\alpha)$ is the capital stock corresponding to the modified golden rule.

The following main result is proved in the paper:

Proposition 3 *Assume $b > 0$ and $g = 0$. Then there is a unique NPA equilibrium, $b^*(b)$, with associated NPA equilibrium consumption stream $c^*(b) = \mathbf{c}(k^*(b))$. Furthermore, $b^*(b)$ is strictly monotone in time, with $\lim_{t\to\infty} b^*_t(b) = k_\infty(\alpha)$, and $c^*(b)$ is efficient, with $\lim_{t\to\infty} c^*_t(b) = f(k_\infty(\alpha))$. Long-term utility adjusted for climate externalities, $\lim_{t\to\infty} a(b^*_t(b))u(c^*_t(b)) = a(k_\infty(\alpha))u(f(k_\infty(\alpha)))$, approaches 0 as $\alpha \to 1$.*

A feasible policy is to require the dynasties to accumulate non-polluting capital only, a case which could be interpreted as cooperation between dynasties. It is shown in the paper that such a policy can be efficient, provided that γ, the parameter measuring to what extent non-polluting capital is less productive, is sufficiently small.

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