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Is intergenerational climate policy more feasible when agents are altruistic?

Master Thesis

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Abstract

Climate policy is failing to succeed for a number of motives. Among them, the intertemporal trade-offs that complicate its implementation, which are directly affected by intergenerational altruism. Research on intergenerational climate policy has often omitted this factor, which directly impacts policy outcomes. In the present paper I investigate what are the consequences of the inclusion of intergenerational altruism on climate policy, and, in particular, on its implementation. Taking as a benchmark a model of intergenerational bilateral social contracts created by (Dao et al., 2017), I introduce a parameter indicating the degree of altruism from generation t towards generation $t+1$ in the utility function of agent t. I find that altruism increases the number of Pareto-improving contracts and consequently the feasibility of implementation of climate policy. Moreover, I encounter that the minimum income required for the existence of Pareto-improving contracts is reduced after the introduction of altruism in the model. Finally, I argue that the introduction of intergenerational altruism calls for less stringent climate policy.

Contents

1 Introduction

The latest report of the Intergovernmental Panel on Climate Change (IPCC) concluded that it is *"likely that warming will exceed 1.5°C during the 21st century"* (Puthalpet, 2022), reflecting the non-success of the goal set in (Paris, 2016) of maintaining the average temperature increase below 1.5°C compared to pre-industrial levels. A reason for the failure in addressing climate change are its intergenerational trade-offs. Whereas the costs of climate policy are incurred by present generations, the benefits of enjoying better climate conditions are enjoyed far into the future. This has relevant implications in the design of climate policy, since it makes investment in mitigation unattractive to current generations. For instance, the debate around critical decisions such as the choice of discount rate (Stern, 2006; Nordhaus, 2017) is ultimately based on the intergenerational dimension of climate change.

Altruism is one demonstrated feature of human behaviour (Aknin et al., 2013; Riddel and Shaw, 2003; Laitner and Juster, 2016; Graham et al., 2017), which directly affects these intergenerational tradeoffs and may also have consequences on the likelihood of application of climate policy. In my paper I examine whether altruism affects the feasibility of implementation of climate policy. I elaborate on the model of bilateral social contracts proposed by (Dao et al., 2017) and introduce altruistic agents who do not only care about their own consumption but also, to a certain extent, about the consumption of the following generation.

Throughout this paper I focus on the case of intergenerational altruism only. This concept englobes the idea that a generation cares about the welfare of the following generations. There are two sorts of intergenerational altruism, pure and impure. It is pure (also known as non-paternalistic[1]) when each generation's utility is a function of the utility of the following generation: $U_t(x_t, U_{t+1})$. This structure generates a loop which leads the utility of the infinite upcoming generations to have an effect on the initial generation's utility: $U_t(x_t, U_{t+1}(x_{t+1}, U_{t+2}(...)))$. In contrast, impure (or paternalistic[2]) altruism arises when a generation cares about a certain component of the future's generation utility (for instance, its consumption level): $U_t(x_t, x_{t+1})$.

Altruism has been widely proven to take part in human decision-making. (Aknin et al., 2013) conduct a study to show that altruism, in the form of shared financial resources, is directly associated with greater happiness, which can be interpreted as a measure of welfare. Their finding is robust to various cultures and income levels, suggesting that it is an intrinsic feature of human nature.

[1]See (Hori and Kanaya, 1989; Hori, 1992; Ray, 1987).

[2]See (Galperti and Strulovici, 2017).

Alternatively, (Riddel and Shaw, 2003) develop a model of bequest value (in this case of natural heritage) and find that respondents are willing to give more than half of their option wealth[3] in order to protect future generations from the potential health risks associated to nuclear waste storage. Also on the basis of bequests, (Laitner and Juster, 2016) expose that around half of the households in their sample show altruistic conducts towards their grown children by intentionally leaving them bequests.

Empirical evidence also indicates that people have intergenerational altruistic preferences with respect to environmental matters. (Graham et al., 2017) analyse an intergenerational time preferences survey carried out in the United Kingdom. They conclude that the majority of respondents have a tendency to choose health and environmental policies which benefit future generations rather than their own, confirming the presence of intergenerational altruism. (Hersch and Viscusi, 2006) used a survey conducted in 1999 to show that there is age variation in this "environmental altruism". According to their study, older people are less willing to incur in higher gasoline prices compared to younger individuals, even after controlling for information about the environment and the individuals' perceived risks.

Intergenerational altruism has been empirically shown to be important, but climate policy has rarely taken it into consideration. There is a wide variety of research on intergenerational climate policy, ranging from instruments such as taxes (Bovenberg and Heijdra, 1998; Kotlikoff et al., 2021), intergenerational social contracts (Dao et al., 2017; Von Below et al., 2016), trust funds (Gerlagh and van der Zwaan, 2001) or public abatement (Bovenberg and Heijdra, 2002). Some of these papers have referred to altruism. (Kotlikoff et al., 2021) uses an Infinitely Lived Agent (ILA) model and argues that the infinitely lived agent structure implicitly includes altruism. Since individuals are infinitely lived, their utility depends on their own utility for the infinite following periods. This would be equivalent to a model with pure intergenerational altruism, where all future utilities are valued. (Gerlagh and van der Zwaan, 2001) also rely on altruism for their model to work: they propose the creation of a trust fund for all natural resources, where each consumer of current and future generations receives a share of it. In order for the system to work, the first generation would have to share the ownership of natural resources with future generations, when they are better off by keeping all the resources for themselves. Only (Pierre-André Jouvet and Vidal, 2000) model intergenerational altruism in an Overlapping Generations (OLG) model and find that steady-state consumption is a

[3] Option wealth is defined as the minimum lifetime payment that an individual would accept prior to the imposition of the policy to bear the risks of the externality

decreasing function of the level of intergenerational altruism. Individuals compensate the loss in welfare due to less consumption with the increase in welfare caused by a better environmental quality for future generations. Nonetheless, they do not address the implications for climate policy design.

This paper is the first, as far as my knowledge goes, to study how intergenerational altruism affects the feasibility of implementation of intergenerational climate policy. It builds upon the OLG model of bilateral social contracts developed in (Dao et al., 2017), in which every generation negotiates an intergenerational contract. In this contract, they decide on the share of income that they invest on mitigation and the transfer that they will receive in the following period. In my setup, I include non-paternalistic intergenerational altruistic agents. I show that altruistic agents are willing, for the same share of transfer received in the following period, to increase their investment in mitigation compared to the non-altruistic scenario. Agents internalise the negative externality of emissions, which translates into higher consumption of the future generation and therefore has an effect on their utility. A reduction in consumption of the first generation caused by a bigger mitigation investment is offset by the growth in consumption of the second generation driven by lower emission levels. As a consequence, I show that introducing altruistic individuals enlarges the set of Pareto-improving contracts in the model.

This paper follows the subsequent structure: In section 2, I explain the model and obtain the equilibrium values, in section 3, I obtain the set of Pareto-improving intergenerational contracts, in section 4, I show the results, in section 5 I interpret the results and discuss the implications for climate policy, and in section 6, I conclude.

2 The Model

In this section, I explain the features of the model, which is a variation of the one in (Dao et al., 2017), and characterise the equilibrium.

2.1 Producers

The production function is a Cobb-Douglas function conformed by polluting physical capital K_t and labour L_t. The environmental externality in this model is represented by the negative effect of the stock of emissions in period $t-1$ on the current period's productivity, $z'(E_{t-1}) < 0$, such that:

$$Y_t = z(E_{t-1})K_t^{\alpha}L_t^{(1-\alpha)}; \qquad \alpha \in (0,1)$$

More concretely, $z(E)$ has the following form:

$$z(E) = Ae^{-|E|}; \qquad A > 0$$

The dynamics of the pollution stock have the following functional form:

$$E_t = (1-\delta)E_{t-1} + K_t - \gamma M_t; \qquad \delta \in [0,1]$$

The parameter δ measures the speed of convergence of the pollution stock to the natural state $\bar{E}$. The natural state is the one that would exist without any human activity, and it is normalized to 0 for simplicity ($\bar{E} = 0$). When the natural state is achieved, the negative externality reaches its minimum and so $z(E) = A$. The mitigation coefficient is given by the parameter γ and indicates the share of effective mitigation, M_t.

Capital is assumed to fully depreciate during each period. Firms choose capital and labour so that its price equals its marginal productivity. Consequently:

$$R_t = z(E_{t-1})\alpha k_t^{\alpha-1} \tag{1}$$

$$w_t = z(E_{t-1})(1-\alpha)k_t^{\alpha} \tag{2}$$

where $K_t/L_t = k_t$ is capital per capita.

2.2 Consumers

The model consists of a constant number of L homogeneous agents that live for two periods, t and $t+1$. When agents are young (period t), they supply labour inelastically to earn labour income w. The agent allocates his disposable income between consumption when he is young, c_t^y, and savings k_{t+1} used for consumption when he is old, c_{t+1}^o.

The system of bilateral social contracts directly affects the choice of the optimal consumption path $(c_t^y, k_{t+1}, c_{t+1}^o)$, emerging as an alternative to savings. More precisely, generation t reduces his savings in the first period by investing in emission mitigation, with the expectation of receiving a transfer in the following period, which will be invested in own consumption, in exchange for the mitigation effort. Agent $t+1$ benefits from this exchange through lower emission levels which translate into higher productivity and ultimately higher wages, which induce a larger consumption.

Without any institutional framework which ensures that the contracts are fulfilled, there could always be place for non-compliance (especially from generation $t+1$). Nevertheless, the agreements are created to be self-enforcing, largely facilitating their implementation. In particular, they are designed to be Pareto-improving[4], meaning that both generations will improve or maintain their utility after the implementation of the contract.

2.2.1 Mitigation and transfers

Following (Dao et al., 2017), all generations are assumed to meet before the beginning of time, and each generation[5] t negotiates with generation $t+1$ for a level of pollution mitigation and a transfer. Generation t offers generation $t+1$ to sign a contract according to which each agent born in generation t invests a portion $m_t \in [0,1)$ of his labour income for mitigation in exchange for a transfer at rate $\tau^o_{t+1} \in [0,1]$ (the transfer cannot be larger than his or her disposable income, since there is no opportunity to borrow in this model) to his gross income in period $t+1$. If both generations reach an agreement, they sign a contract (m_t, τ^o_{t+1}). In case an agreement is not reached, $(m_t, \tau^o_{t+1}) = (0,0)$. As shown in Figure 1, the mitigation share m_t is paid in period t and the transfer τ^o_{t+1} in period $t+1$. The mitigation investment $M_{t+1} = m_t \cdot I_t$ (where $I_t = w_t(1-\tau^y_t)$ is the disposable income of generation t; and τ^y_t is the transfer paid to generation $t-1$) becomes effective in period $t+1$.

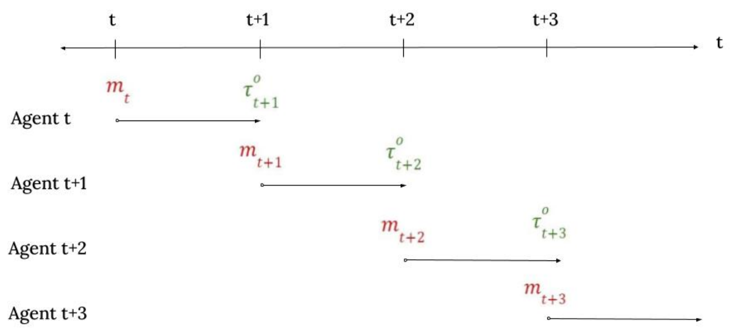

Figure 1: Timeline of the bilateral social contracts

[4]In Section 3 I explain in detail how the Pareto-improving design is achieved.
[5]From this point onwards, I index each generation with its birth year.

(Dao et al., 2017) propose a framework where the utility of generation t depends just on the consumption in both periods t and $t+1$, which constitutes its lifetime. In this paper I extend their model by including a utility function where the utility of agent t depends on its own consumption in both periods and, to some extent, on the lifetime consumption of generation $t+1$:

$$U_t = \ln c_t^y + \beta \ln c_{t+1}^o + \eta(\ln c_{t+1}^y + \beta \ln c_{t+2}^o)$$

where $\beta \in (0, 1)$ is the time preference parameter and $\eta \in [0, 1]$ is the parameter that indicates the degree of altruism. As η approaches zero, the model becomes the one developed in (Dao et al., 2017), where any intergenerational-preferences concern is reduced to the choice of the discount rate. Whether the discount rate is higher or lower represents that an agent gives more or less weight to all future periods proportionally when maximizing welfare. The simplification of such a complex matter to a single parameter is common practice in the climate literature. Even more sophisticated versions of the discount rate (i.e. hyperbolic discounting, where time-inconsistent preferences are reflected) are lacking description capacity. Key papers such as (Nordhaus, 2017) or (Stern, 2006) discuss in depth the adequate value for the discount rate, used for the estimation of the social cost of carbon, but ignore other factors such as altruism.

The parameter introduced in this paper puts emphasis on the myopic behaviour of individuals. As a complement to the discount rate, η gives a larger weight only to the closest generation (or the ones that are considered to be relevant). Hence, the inclusion of an altruistic parameter brings climate policy closer to the real world by reflecting the preferences of individuals more accurately.

The specified utility function represents paternalistic altruistic preferences, given that the utility of generation t depends only on one component (or more than one, but not on the whole utility function) of the utility of generation $t+1$. The choice of paternalistic over non-paternalistic altruism is based in a simple fact. Independently of whether agent t's utility is a function of the utility of the infinite upcoming generations, the proposed intergenerational social contracts are bilateral. That is, they are negotiated between every pair of contemporary generations and have no effect on the utility of other generations. Hence, even if I included non-paternalistic utility functions in the model, the results and conclusions would not vary, despite severely complicating the calculations.

2.3 Equilibrium

In the equilibrium of the model, firms choose factor prices that equal their marginal productivity and agents choose utility-maximising values for current consumption, savings and future consumption.

The optimal equilibrium values for consumption and savings depend on the agreed mitigation share and transfer rate, and agents will only sign a contract that yields a higher utility than in a scenario without such a contract. Given the agreement (m_t, τ^o_{t+1}), agent t maximises:

$$\max_{c^y_t, c^o_{t+1}, k_{t+1}} \quad U_t = \ln c^y_t + \beta \ln c^o_{t+1} + \eta(\ln {c^y_{t+1}}^* + \beta \ln {c^o_{t+2}}^*)$$

$$\text{s.t.} \quad c^y_t + k_{t+1} \leq I_t(1 - m_t)$$

$$c^o_{t+1} \leq k_{t+1} R_{t+1}(1 + \tau^o_{t+1})$$

In words, agent t chooses the set of own consumption and savings that maximises his or her utility. He or she is constrained to his or her consumption plus savings in period t being smaller or equal than his or her net income, and his or her consumption in period $t+1$ being smaller or equal than the savings times the return to capital and plus the transfer. Agent t assumes that agent $t+1$ will also choose consumption and savings ${c^y_{t+1}}^*, {c^o_{t+2}}^*$ and k^*_{t+2}. Given the structure of the model, these optimal values are equivalent to those of agent t, but delayed one period. This is an important assumption, because without it the analysis would yield different results.

Following the maximisation problem of the consumer (see Appendix 1) I obtain the subsequent equilibrium values for agent t ($\forall t$):

$$k_{t+1} = \frac{\beta}{1+\beta} I_t(1 - m_t) \tag{3}$$

$$c^y_t = \frac{1}{1+\beta} I_t(1 - m_t) \tag{4}$$

$$c^o_{t+1} = \alpha z(E_t)(\frac{\beta}{1+\beta} I_t(1 - m_t))^\alpha (1 + \tau^o_{t+1}) \tag{5}$$

The above equations reflect the consumption and savings choices of agent t at equilibrium. These are proportional to the disposable income of the agent, $I_t(1 - m_t)$ and $I_{t+1}(1 - m_{t+1})$, where $\frac{\beta}{1+\beta}$ represents the proportion of disposable income which is saved. Conditions (1)-(5), together with the law of motion of capital $K_{t+1} = k_{t+1}$ (under the assumption $L_t = 1\ \forall t.$ and that capital fully depreciates each period) and the dynamics of the pollution stock characterise the equilibrium of the model.

In addition, the total value of the transfer at rate τ^o_t received by generation $t-1$ must equal the total value of the transfer at rate τ^y_t paid by generation t under the contract (m_{t-1}, τ^o_t). Both τ^o_t and τ^y_t must satisfy the budget balance condition $w_t \tau^y_t = R_t k_t \tau^o_t$ at equilibrium. Consequently,

$$\tau^y_t = \frac{\alpha}{1-\alpha} \tau^o_t \tag{6}$$

which is the last equation that describes the equilibrium.

The equilibrium values for consumption and savings are independent of altruism, represented by η. Nevertheless, altruism does influence the optimal level of utility. In the following section I use variations in optimal utility levels, which are dependent on altruism, before and after the contract to identify the set of Pareto-improving intergenerational contracts.

3 Pareto-improving intergenerational contracts

In this section, I search for contracts (m_t, τ^o_{t+1}) which are Pareto-improving, that is, which rise the utility of at least one generation without decreasing the utility of the other. The existence of Pareto-improving contracts requires that the variation in utility before and after the contract is greater or equal than 0 for both generations. In other words, for generation t, an increase in mitigation effort from 0 to m_t must be compensated by an increase in the transfer rate from 0 to τ^o_{t+1} and also an increase in consumption of generation $t+1$ (which positively affects U_t) attained from a reduction in emission levels compared to the scenario without mitigation effort m_t. The same should apply to generation $t+1$, for whom a decrease in utility after the transfer τ^o_{t+1} must be recompensed with higher productivity which leads to higher consumption levels, derived from the larger mitigation effort of generation t.

Under the contract (m_t, τ^o_{t+1}), the indirect utility of generation t (depending on optimal values of consumption (3)-(5)) is given by:

$$\begin{aligned} U_t^{(m_t,\tau^o_{t+1})} &= \ln(\frac{1}{1+\beta} I_t(1-m_t)) + \beta \ln(\alpha z(E_t)(\frac{\beta}{1+\beta} I_t(1-m_t))^{\alpha}(1+\tau^o_{t+1})) \\ &+ \eta(\ln(\frac{1}{1+\beta} I_{t+1}(1-m_{t+1})) + \beta \ln(\alpha z(E_{t+1})(\frac{\beta}{1+\beta} I_{t+1}(1-m_{t+1}))^{\alpha}(1+\tau^o_{t+2}))) \end{aligned}$$

where m_{t+1} and τ^o_{t+2} constitute the agreement signed (or not reached) between generations $t+1$ and $t+2$, and is taken as given[6].

Instead, without a contract:

[6] Since the next step will involve calculating the variation in utility before and after the contract (m_t, τ^o_{t+1}), the contract (m_{t+1}, τ^o_{t+2}) will be irrelevant for the outcome.

$$U_t^{(0,0)} = \ln(\frac{1}{1+\beta}I_t) + \beta\ln(\alpha z(E_t)(\frac{\beta}{1+\beta}I_t)^\alpha) + \eta(\ln(\frac{1}{1+\beta}I_{t+1}(1-m_{t+1}))$$
$$+ \beta\ln(\alpha z(E'_{t+1})(\frac{\beta}{1+\beta}I'_{t+1}(1-m_{t+1}))^\alpha(1+\tau^o_{t+2}))) \quad (7)$$

where $z(E'_{t+1})$ and I'_{t+1} represent future emissions and income under no mitigation effort m_t.

Hence, the variation in utility $\Delta U_t = U_t^{(m_t,\tau^o_{t+1})} - U_t^{(0,0)}$ before and after the contract is[7]:

$$\Delta U_t = \ln(1-m_t) + \alpha\beta\ln(1-m_t) + \beta\ln(1+\tau^o_{t+1}) + \eta((1+\alpha\beta)\ln(\frac{1-\alpha(1+\tau^o_{t+1})}{1-\alpha}(1-m_t)^\alpha)$$
$$+ \frac{\beta(\beta+\gamma+\gamma\beta)}{1+\beta}m_tI_t)$$

In the case of generation $t+1$, the utility under the same contract is as follows:

$$U_{t+1}^{(m_t,\tau^o_{t+1})} = \ln(\frac{1}{1+\beta}I_{t+1}(1-m_{t+1})) + \beta\ln(\alpha z(E_{t+1})(\frac{\beta}{1+\beta}I_{t+1}(1-m_{t+1}))^\alpha(1+\tau^o_{t+2}))$$
$$+ \eta(\ln(c^y_{t+2}) + \beta\ln(c^o_{t+3}))$$

Instead, when $(m_t, \tau^o_{t+1}) = (0,0)$:

$$U_{t+1}^{(0,0)} = \ln(\frac{1}{1+\beta}I_{t+1}(1-m_{t+1})) + \beta\ln(\alpha z(E_{t+1})'(\frac{\beta}{1+\beta}I'_{t+1}(1-m_{t+1}))^\alpha(1+\tau^o_{t+2}))$$
$$+ \eta(\ln(c^y_{t+2}) + \beta\ln(c^o_{t+3}))$$

where the second term (the altruistic component towards agent $t+2$) is unaffected by the contract (m_t, τ^o_{t+1}).

The variation in utility for agent $t+1$ is described by:

$$\Delta U_{t+1} = (1+\alpha\beta)\ln(\frac{1-\alpha(1+\tau^o_{t+1})}{1-\alpha}(1-m_t)^\alpha) + \frac{\beta(\beta+\gamma+\gamma\beta)}{1+\beta}m_tI_t \quad (8)$$

Mathematically, a Pareto-improvement requires that the variation of utility before and after the contract for both generations is positive or equal to 0, that is, $\Delta U_t, \Delta U_{t+1} \geq 0$. Any point where ΔU_t is equal to 0 represents that generation t is indifferent between signing and not signing the contract. Equivalently, if ΔU_{t+1} equals 0, generation $t+1$ will remain neutral when negotiating the contract. In accordance, $\Delta U_t = 0$ and $\Delta U_{t+1} = 0$ are interpreted as the indifference curves of generations t and $t+1$, respectively.

[7]The complete derivation can be found in Appendix 2

4 Results

In this section I proceed to show the implications of altruism on the set of Pareto-improving contracts. Once the indifference curves of generations t and $t+1$ are represented, the area remaining between these two functions corresponds to the set of contracts that improve the utility of both generations compared to a case without contracts.

I differentiate two cases in this analysis. The indifference curve of generation $t+1$, to which I will refer as Ω from here onwards, maintains its shape regardless whether altruism is induced. Since the altruism of generation $t+1$ is directed towards generation $t+2$, and this last one is unaffected by the contract between the previous two generations, it does not make a difference in the analysis[8]. In the case of generation t, however, the indifference curves are directly affected by the altruistic parameter η. The indifference curve (from here onwards denoted as ϕ) of generation t presents, hence, two particular scenarios. It can be the case that the variation in U_t is zero ($\Delta U_t = 0$) because the variation in lifetime consumption before and after the contract is zero for both generations, or that the decrease in the lifetime consumption of agent t is compensated by the increase in the lifetime consumption of agent $t+1$. This last case is a unique particularity of this model, because only the fact that consumption of agent $t+1$ is a part of the utility of agent t (altruism) allows for a trade-off between the consumption of both agents that can make agent t indifferent. Hence, there are two different cases to study.

4.1 Case I: No variation in utility derived from own lifetime consumption

The indifference curves represented in Figure 2 show the set of contracts that leave the utility derived from own lifetime consumption of agents t and $t+1$ unaffected by the contract (i.e. $\Delta(c_t^y + \beta c_{t+1}^o), \Delta(c_{t+1}^y + \beta c_{t+2}^o) = 0$). As altruism increases, the area that corresponds to the set of Pareto-improving contracts (the area between both curves) gets larger.

In particular, the case where ΔU_t and ΔU_{t+1} equal 0 corresponds to the upper intersection of Ω and ϕ. These are, for different values of η, the only possible contracts where $m_t > 0$ and $\tau_{t+1}^o > 0$ that leave the utility of both agents the same before and after the contract. This scenario is only attainable if the variation of utility derived from lifetime consumption for agent t and agent $t+1$ is zero. That is, the implementation of the contract does not induce any change in the consumption choices of any of the two individuals, or, if consumption choices vary, the new alternatives yield

[8] This is also the reason why the choice of pure or impure intergenerational altruism is not relevant for this study.

the same utility as before. As depicted in Figure 2, under no variation in lifetime utility derived from consumption and for every different value of altruism, the mitigation shares m_t are maximised, subject to the contracts being feasible. Whereas in terms of the welfare of agents t and $t + 1$, not investing in mitigation is equivalent to mitigating an amount m_t corresponding to the upper-intersection of Ω and ϕ, it is still true that for future generations a positive mitigation will always be better (up to $\bar{E} = 0$). Then, if agents are able to identify this (although it is not specified in their utility functions, it can be common knowledge that lower emissions means a better future for upcoming generations), and since they are indifferent between both cases, maximising mitigation is more beneficial from a general welfare perspective.

The case of no variation in utility derived from lifetime consumption for agents t and $t + 1$ is only feasible for very low levels of altruism. For instance, as depicted in Figure 2, for $\eta = 0.5$, the intersection between Ω and ϕ occurs at a point where $\tau^o_{t+1} > 1$. A transfer rate larger than 1 implies that generation $t + 1$ has to transfer an amount bigger than his or her disposable income. The only opportunity to achieve this would be if agent $t+1$ borrowed money. Nonetheless, in this model borrowing is not an option because the only possibility would be to borrow money from agent t (since it is the only generation alive besides from generation $t+1$), which happens to be the the generation that has to be paid. Hence, any intergenerational contract where $\tau^o_{t+1} > 1$ is unfeasible, and there are only plausible contracts without variation in utility derived from own lifetime consumption for both agents for low levels of η.

4.2 Case II: Variation in utility derived from own lifetime consumption

The second scenario arises when the contract induces a decrease in the utility yielded by own lifetime consumption of agent t and an increase in that of agent $t + 1$, so that agent t derives the same total utility before and after the contract (U_t depends on own and agent $t + 1$'s consumption). If instead the rise of utility obtained from own lifetime consumption of agent t was compensated by a reduction in the utility derived from lifetime consumption of agent $t + 1$, agent t would remain with the same utility before and after the contract, but agent $t + 1$ would experience a loss of utility, and therefore the contracts would not be Pareto-improving.

Hence, the only Pareto-improving possibility occurs when the variation of own consumption of agent t is negative and the variation of own consumption of agent $t + 1$ ($= \Delta U_{t+1}$) is positive. Also, a situation where the variation in utility derived from consumption of agent t is positive and that of agent $t + 1$ is zero would reflect a Pareto-improvement.

Within the case involving variation in consumption for at least one of the agents, there are three possibilities that are clearly distinguishable in Figure 2. The first one is $\Delta U_t = 0, \Delta U_{t+1} > 0$. Every contract located at a point conforming the function ϕ (with the exception of the intersection with Ω) meets these conditions. The second one is $\Delta U_t > 0, \Delta U_{t+1} = 0$, and is composed of every point forming the function Ω (except the intersection). Finally, every contract in-between the area of both curves satisfies the conditions $\Delta U_t > 0$ and $\Delta U_{t+1} > 0$.

Regardless of how the Pareto-improvement is reached, the effect of altruism in the set of Pareto-improving agreements is notorious. Under a positive η, the fact that agent t derives utility from the consumption of agent $t+1$ causes the first one to make a bigger mitigation effort for the same transfer rate, due to lower emission levels positively affecting agent $t+1$'s consumption. Following the same reasoning, agent t will accept receiving a lower future transfer for the same mitigation effort (compared to a case with lower altruism), because a lower transfer rate τ^o_{t+1} translates into a higher consumption for agent $t+1$.

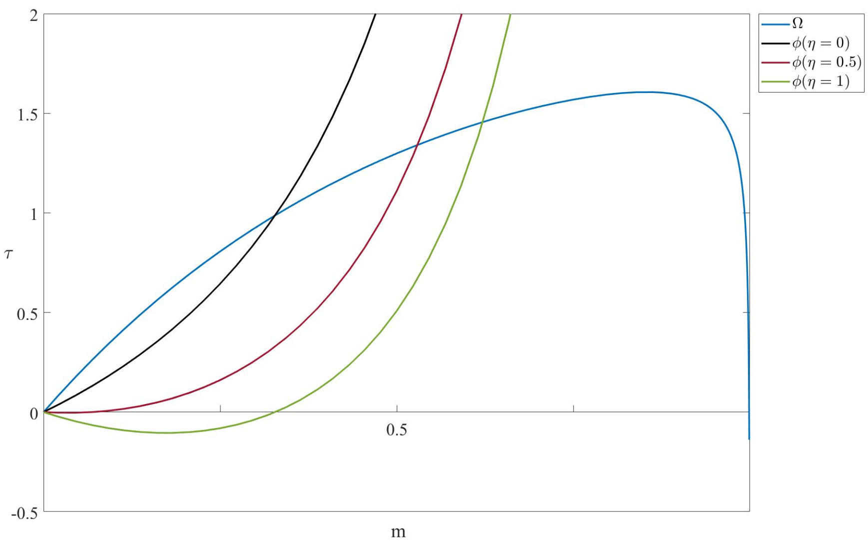

Figure 2: Set of Pareto-improving contracts under no variation in consumption

When agent t gives as much weight to his own consumption as to agent $t+1$'s consumption ($\eta = 1$), there is a feasible case where generation t invests a positive share of their disposable income on mitigation when young ($m_t > 0$) and, instead of receiving a transfer, he or she transfers the share τ_{t+1}^o to the youngest generation, $t+1$. For this same η, agent t is willing to invest a maximum share of approximately 0.3 of his or her disposable income when young without receiving any transfer when old. The intuition behind this is that a negative τ_{t+1}^o positively affects the income, and consequently consumption in both periods, of agent $t+1$. This same transfer rate only has an effect on consumption of the second period for agent t and, since the consumption of both agents is equally weighted in U_t ($\eta = 1$), the gains derived from a larger consumption of generation $t+1$ overweight the loss from a reduced consumption of generation t. Although this an extreme scenario that is likely to be unrealistic, it reflects the consequences of altruism not just on the amount, but also on the nature of feasible contracts and therefore on the likelihood of implementation of climate policy.

For a moderate magnitude of altruism (i.e. $\eta = 0.5$), a very large mitigation effort is very costly in terms of future transfers. A mitigation investment of 50% of the disposable income when young would require, for this magnitude of η, a transfer at a rate larger than 100%. As previously stated, such an agreement could not be reached because generation $t+1$ would need to transfer a quantity which is larger than his or her disposable income.

For values of η smaller than 0.5 there are very few or no Pareto-improving contracts with a mitigation effort $m_t = 0.5$, that is, large mitigation investments require a significant degree of altruism. The price of mitigation (i.e. the transfer rate) grows exponentially as m_t increases, and this is the case even for very large values of altruism.

Figure 3 shows, in a three-dimensional plot, how the set of Pareto improving contracts (the space in-between the indifference functions, including the curves) increases as η gets larger. When $\eta = 0$ the set of plausible contracts coincides with the one obtained in (Dao et al., 2017), and it grows bigger as η affects the shape of the indifference curve of agent t, depicted in yellow. Once again, Figure 3 reveals how the indifference curve of agent $t+1$, in blue, is independent of the degree of altruism. The function is cut when the transfer rate reaches 1. The figure suggests that the effect of η in the set of Pareto-improving agreements would be even more sizeable if borrowing were possible in the model.

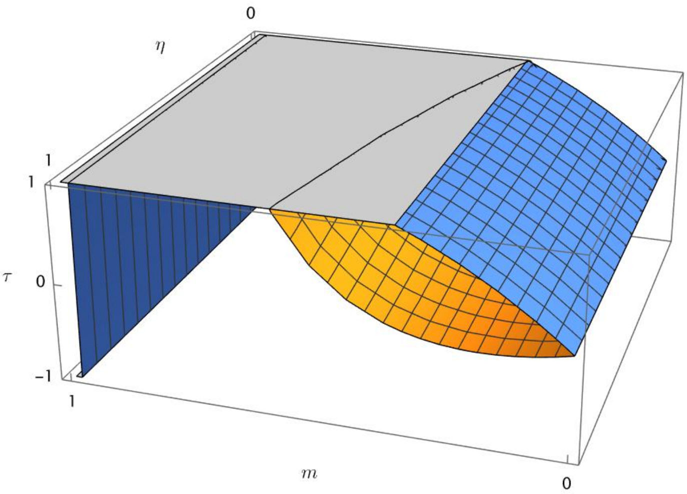

Figure 3: Relationship between the set of Pareto-improving contracts and η

4.3 The role of income

As clarified in Appendix 4, for the representation of the previous four figures I gave values to the parameters α, β and γ. I also selected a level of income that allowed for the existence of Pareto-improving possibilities. However, this is not the case for every level of income; if it is not larger than a certain threshold, there is no place for a feasible implementation of climate policy.

(Dao et al., 2017) pointed out that for the existence of a Pareto-improving set of contracts the derivative evaluated at 0 of Ω (i.e. $\Omega'(0)$) should exceed the derivative at 0 of ϕ (i.e. $\phi'(0)$). The first derivative represents the marginal gain of generation $t+1$ after an increase in the mitigation share from zero to m_t (or, in other words, the maximum willingness to pay). The second derivative reflects the marginal loss of generation t after increasing the mitigation effort from zero to m_t (or the minimum willingness to accept). The marginal gain for generation $t+1$ must be larger than the marginal loss of generation t for a marginal increase in the mitigation share. That is, the maximum transfer that generation $t+1$ is willing to pay for a marginal increase in mitigation must be larger than the minimum transfer generation t is willing to accept for that same marginal increase. (Dao et al., 2017) looked for the minimum income that satisfied $\Omega'(0) \geq \phi'(0)$ and found:

$$I^* = \frac{\alpha(1+\alpha\beta)(1+\beta)^2}{(1-\alpha)(\beta+\gamma+\beta\gamma)\beta^2}$$

Following the same reasoning (see Appendix 3), I obtain an altruism-dependent threshold of income that has the following shape:

$$I^* = \frac{\alpha(1+\beta)(1+\alpha\beta)(-1+\beta(-1+2(-1+\alpha)\eta))}{(-1+\alpha)(1+2\eta)(\beta+\gamma+\beta\gamma)\beta^2}$$

which converges to the previous threshold as $\eta \to 0$. Under the choice of parameters discussed in Appendix 4, (Dao et al., 2017) obtain a threshold income $I^* \approx 1.2744$. When altruism is introduced, the minimum income requirement gets relaxed. For instance, for an $\eta = 0.5$ the income threshold drops to $I^* \approx 0.8209$. More precisely, the relationship between the income threshold and altruism has the following appearance:

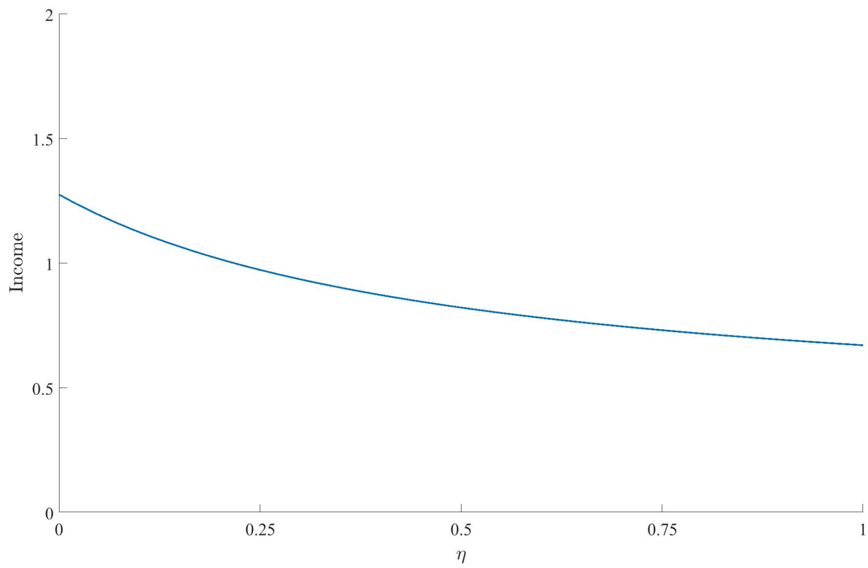

Figure 4: Relation between income threshold and degree of altruism

As exposed in Figure 4, the higher the degree of altruism, the lower the value of the income threshold. Intergenerational altruism leads generation t to be willing to accept a lower transfer for the same mitigation effort (a downward shift of their indifference curve), since being affected by the consumption of the future generation makes them internalise the negative externality on productivity and accordingly on consumption. This increases the likelihood of the willingness to pay of generation $t+1$ being larger than the willingness to accept of generation t. Nonetheless, the marginal effect of the altruistic parameter on the income threshold is decreasing on η. Moreover, there is an horizontal asymptote for an income threshold of around 0.6, which would imply that there is a lower boundary on the threshold for every η. That is, regardless of the degree of altruism (as $\eta \to \infty$) there is a minimum income threshold that cannot be surpassed. If the income level is lower than this amount, there is no place for Pareto-improving contracts, and no level of altruism can avoid this.

5 Discussion

The analysis carried out in this paper shows that the introduction of impure intergenerational altruism into a model of bilateral social contracts enlarges the possibilities, with respect to a situation without altruism, of implementation of these Pareto-improving contracts. The results obtained in (Dao et al., 2017) and reviewed in this paper are less strict once altruism is taken into account. In the evaluated framework, for a same mitigation effort from generation t, altruism leads to a lower transfer requirement for generation $t+1$. Alternatively, for a same transfer rate paid by generation $t+1$, the previous generation is willing to invest a larger share of his or her disposable income in mitigation. In other words, mitigation efforts become cheaper, since the price to pay (i.e. the transfer rate) for a same mitigation share is lower under a framework with altruistic agents.

The relaxations of the requirements for Pareto-improving policy are driven by the effect of the second generation's consumption on the first generation's utility. Since the negative effect of emissions translates into a lower consumption for the future generation, generation t partly internalises the negative externality and is more flexible when investing in mitigation. The inclusion of altruism allows climate policy to realistically reach mitigation shares that would not be achieved if altruism was not in place. Another result in line with the previous is the change in the minimum income requirements. In the initial scenario without altruism, there was a minimum income level needed for Pareto-improving agreements to exist. I prove that this threshold is lower in the presence of altruism, for any positive η.

Although the outcomes of this study only apply to the particular case of intergenerational bilateral social contracts, it is safe to say that, given the nature of the trade-offs, the impacts are likely to be similar for other sorts of intergenerational climate policy. The implications of this study on climate policy are straightforward. If climate policymakers include intergenerational altruism in a model, it will increase the feasibility of implementation of that policy by making investments in climate mitigation relatively cheaper. We can imagine what would happen, for instance, in the case of optimal taxation of emissions. Let us think of a similar framework, an Overlapping Generations model where there is a negative externality of emissions that affects future productivity and eventually consumption. By introducing altruism, agents partially internalise the externality, and therefore the optimal tax would be lower compared to a scenario without altruism, where the tax has to induce consumers to completely internalise the negative external effect of emissions. Hence, altruism acts, to some extent, as a substitute for climate policy. The more altruistic agents are, the lower the need for stringent climate policy.

As a consequence, environmental awareness or educational policies that inspire altruistic behaviours with respect to future generations can be used as alternatives or complements to other types of climate policy and obtain similar outcomes. Market-based policies as taxation or subsidies tend to be more cost-effective[9] than awareness policies. However, educational policies can be used as a complement in order to make the others less strict.

6 Conclusion

The present paper evaluates the impact of the introduction of altruism on the feasibility of implementation of climate policy. The introduction of impure altruism into the scheme of bilateral social contracts from (Dao et al., 2017) leads to an increased number of Pareto-improving agreements between generations t and $t+1$. Moreover, the minimum income threshold required for the existence of Pareto-improving contracts is reduced as altruism increases.

Hence, the implementation of intergenerational climate policy is more feasible in the presence of altruism. The underlying reason behind this phenomenon is the partial internalisation of the negative externality of emissions from generation t. These results have implications in the optimal design of climate policy. Namely, altruism calls for the application of less strict climate policy, because agents are doing part of the internalisation of the externality themselves. This implies that policies that induce intergenerational altruism can function as a substitute, or a complement, to climate policy.

6.1 Limitations and future research

There are a number of limitations in this study. The first one has to do with the design of the model. One of the assumptions is that agents are supposed to meet before the beginning of time to

[9]For instance, (Anderson et al., 2009) show in the case of alcohol that taxation is significantly more cost-effective than information or educational policies.

sign the contract. Of course, this assumption is theoretical, but in order to obtain applicable results it would be important to make assumptions which are not so far from reality. Another limitation of the framework is that, although contracts are self-enforcing (because they are Pareto-improving), the timing of the contract allows generation $t + 1$ not to pay the agreed transfer after generation t has made the mitigation effort. The proposed scheme would require some type of outside institution that made sure that the contracts were carried out adequately.

In the motivation of this paper I argued that policymakers rarely take altruism into account. There may be an explanation for why they ignore intergenerational altruism. As seen before, optimal climate policy is less strict when altruism is taken into account. Knowing that we are still failing to address climate change effectively, policymakers may be tempted to intentionally overstate optimal climate policy so that risks are reduced. (Tol, 2009) explains that the few countries which are carrying out climate policies have a tendency to introduce policies which are excessively stringent, even for scenarios with high damages, which could explain why altruism is commonly avoided.

In terms of future research, it could be evaluated whether the impact of altruism is the same for other sorts of climate policy or whether it differs depending on the instrument. In addition, it would be interesting to empirically test the theoretical results from this paper. That is, to investigate whether countries with different degrees of altruism (if there happen to be significant differences) have succeeded differently when it comes to climate policy implementation.

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A Appendix

A.1 Consumer maximization problem

The Lagrangian function corresponding to the consumer's optimisation problem is:

$$\begin{aligned} L &= \ln c_t^y + \beta \ln c_{t+1}^o + \eta(\ln c_{t+1}^y + \beta \ln c_{t+2}^o) \\ &\quad -\lambda_1(c_t^y + k_{t+1} - I_t(1-m_t)) \\ &\quad -\lambda_2(c_{t+1}^o - k_{t+1}R_{t+1}(1+\tau_{t+1}^o)) \end{aligned}$$

Taking the partial derivatives with respect to the variables of interest:

$$\frac{\partial L}{\partial c_t^y} = \frac{1}{c_t^y} - \lambda_1 = 0$$

$$\frac{\partial L}{\partial k_{t+1}} = -\lambda_1 + \lambda_2 R_{t+1}(1+\tau_{t+1}^o) = 0$$

$$\frac{\partial L}{\partial c_{t+1}^o} = \frac{\beta}{c_{t+1}^o} - \lambda_2 = 0$$

Joining the first three equations I obtain the following relationship:

$$\frac{1}{c_t^y} = \frac{\beta}{c_{t+1}^o} R_{t+1}(1+\tau_{t+1}^o)$$

Plugging the constraint $c_t^y + k_{t+1} = I_t(1-m_t)$, $c_{t+1}^o = k_{t+1}R_{t+1}(1+\tau_{t+1}^o)$, I can solve for k_{t+1}:

$$k_{t+1} = \frac{\beta}{1+\beta} I(1-m_t)$$

Then, solving for c_t^y is straightforward:

$$c_t^y = \frac{1}{1+\beta} I(1-m_t)$$

Given the definitions of savings k_t and return to capital R_t, I can define c_{t+1}^o as:

$$c_{t+1}^o = \alpha z(E_t)(\frac{\beta}{1+\beta} I_t(1-m_t))^{\alpha}(1+\tau_{t+1}^o)$$

A.2 Utility differentials

First, for generation $t+1$ I subtract $U_{t+1}^{(m_t,\tau^o_{t+1})} - U_{t+1}^{(0,0)}$. Given the following:

$$\Delta z(E_{t+1}) = e^{E'_{t+1}-E_{t+1}} = e^{\frac{\beta+\gamma+\beta\gamma}{1+\beta}m_t I_t}$$

$$\Delta I_{t+1} = 1 - \frac{\alpha\tau^o_{t+1}}{1-\alpha}(1-m_t)^\alpha$$

We obtain:

$$\Delta U_{t+1} = (1+\alpha\beta)\ln(1-\frac{\alpha\tau^o_{t+1}}{1-\alpha}(1-m_t)^\alpha) + \beta\ln(e^{\frac{\beta+\gamma+\beta\gamma}{1+\beta}m_t I_t})$$

In the case of generation t, by subtracting $U_t^{(m_t,\tau^o_{t+1})} - U_t^{(0,0)}$ I get:

$$U_t^{(m_t,\tau^o_{t+1})} - U_t^{(0,0)} = (\alpha-1)\frac{\beta}{1-m_t} + (1+\beta)\ln(1-m_t) + \beta(1+\tau^o_{t+1}) + \eta\Delta U_{t+1}$$

And therefore:

$$\Delta U_t = \ln(1-m_t) + \alpha\beta\ln(1-m_t) + \beta\ln(1+\tau^o_{t+1}) + \eta((1+\alpha\beta)\ln(\frac{1-\alpha(1+\tau^o_{t+1})}{1-\alpha}(1-m_t)^\alpha)$$
$$+ \frac{\beta(\beta+\gamma+\gamma\beta)}{1+\beta}m_t I_t)$$

A.3 Income threshold derivation

A necessary condition for the existence of Pareto improving social contracts is that the derivative of Ω with respect to m evaluated at 0 is larger than the derivative of ϕ with respect to m evaluated at 0.

$$\Omega'(0) = \frac{(1-\alpha)(-\alpha + \frac{I\beta(\beta+\gamma+\beta\gamma)}{(1+\beta)(+\alpha\beta)})}{\alpha}$$
$$\phi'(0) = \frac{\alpha + \frac{1}{\beta} - \frac{\eta(1-\alpha)(-\alpha+\frac{I\beta(\beta+\gamma+\beta\gamma)}{(1+\beta)(+\alpha\beta)})}{\alpha}}{1+\eta}$$

I set $\Omega'(0) \geq \phi'(0)$ and isolate I. The minimum income that satisfies this inequality is given by:

$$I^* = \frac{\alpha(1+\beta)(1+\alpha\beta)(-1+\beta(-1+2(-1+\alpha)\eta))}{(-1+\alpha)(1+2\eta)(\beta+\gamma+\beta\gamma)\beta^2}$$

A.4 Parameter choice

In order to represent the indifference curves in Figures 2 and 3, and following the reasoning in (Dao et al., 2017), I choose a value of $\beta = 0.7$ that gives a realistic savings rate of approximately 40%. The mitigation coefficient γ takes value 1 and the share of capital α equals 0.3. For the first four figures I chose a value of income $I = 2.5$ which allows for the existence of a set of Pareto-improving contracts for any level of η.