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Intergenerational Fairness and Climate Change Adaptation Policy: An Economic Analysis

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Abstract: Compared to existing needs, climate change adaptation policies are significantly deficient. Since many adaptation measures have the feature of a local public good, and since benefits accrue to later generations mainly, most environmental economists would argue that the public goods issue is the most plausible reason why incentives are often insufficient for achieving the optimal level of adaptation. Within a stylized overlapping generation model, we show that adaptation is subject to severe intergenerational consistency problems, if pure self-interest is a feature of the generation's behavior. This explains among others why too little is invested into climate change adaptation. We also show that if the distribution of income between generations matters or if generations behave altruistic, this consistency conflict can be solved and offers possibilities for policy intervention.

Keywords: climate change adaptation policy, intergenerational fairness and equity

1. Introduction

Today atmospheric carbon concentrations have already reached levels such that due to the inertia of the climate system global warming is unavoidable to some degree, even if emissions were cut back completely. This could, combined with a growing population and inappropriate land use, lead to a significant increase in the frequency, intensity, and the duration of weather-related extreme events such as floods (e.g. IPCC, 2014). Feyen et al. (2012), for example, estimate that in Europe the annual damages caused by river flooding will more than triple till the end of the century. Based on recorded observations, the OcCC (1999) reports that in the Alps autumn and winter precipitation has already risen by more than 30% over the last 100 years. Furthermore, model-based predictions suggest that climatic warming will cause significantly more and severe flood events in the Swiss Central Plateau (Mittelland) and southern Switzerland, which could imply additional flood-related costs in the order of magnitude of several hundred million Swiss francs per year unless effective adaptation measures through flood protection are taken.

Consequently, mitigation cannot be the only policy response to the threat of global climate change. Alternatively, there exists the possibility to reduce a region's vulnerability by adapting to impacts of global warming.[1] Thereby, adaptation can cover a wide range of different measures, including early storm warning on the one end and investments in infrastructures such as dams for preventing against flooding on the other. However, compared to the projected needs, adaptation policies today are lagging behind significantly (see Rayner and Jordan, 2010). Environmental economists typically argue that many adaptation measures such as flood protection have the feature of a local public good, and since both the present and future generations will benefit from such an investment, this combined with the public goods issue is the most mentioned reason why incentives are often deficient. A particular example in this context is New Orleans, Louisiana (for a detailed discussion, see Wolfe, 2008). Its geography as well as its natural environment allows for destructive hurricanes as the city's history has demonstrated. A levee system was constructed in the 1940s for providing protection to the city, but three subsequent hurricane strikes indicated that New Orleans remained vulnerable to flooding. After each disaster, politicians promised to prevent a similar catastrophe, and each time they failed to adequately fix the levees. An assessment of the levee system through the White House (2006) after Hurricane Katrina concluded: "New Orleans has now been flooded by hurricanes six times over the past century; in 1915, 1940, 1947, 1965, 1969, and 2005. It should not be allowed to happen again" (White House, 2006).

Political rhetoric, which promises that decisions taken in the present can positively affect the welfare of generations to come, sounds appealing. But as the example of New Orleans demonstrates, political rhetoric frequently surpasses political action. Levees may protect present-generation voters, but future generations also can enjoy the benefit of a well-protected city that has not suffered a catastrophe like Hurricane Katrina. That future generations will benefit only if current generations pay is an example of an intergenerational externality, which leads to an underinvestment in disaster protection as economists argue. And since the unborn cannot vote in today's elections, elected officials

[1]There exists strategic interaction between mitigation and adaptation, as was analyzed in detail by Buob and Stephan (2011).

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normally focus on the short-term interests of current voters and largely ignore long-term problems that will arise after they have left office. Many lawyers (e.g., see Frischmann, 2005, Mank, 2009, or Wolfe, 2008) therefore argue that the American political institutions as well as the legal system do not adequately protect the interests of future generations.

A different explanation is given by historian. Pfister (2009) for example argues that insufficient investment into climate change adaptation is the result of what is termed "disaster gap." While communities of Western and Central Europe for many centuries were regularly hit by natural hazards and disasters, the evidence of such events diminished over the late nineteenth and early twentieth century. For Switzerland, for example, the time series of severe disasters during the period between 1806 and 2007 shows that recorded losses of life and damages were relatively infrequent. This "disaster gap" promoted the loss of what is termed "disaster memory," and hence, the risk of natural hazards was increasingly disregarded by societies.

This paper provides an explanation by applying an economic perspective. Markets can under particular circumstances grant efficiency but are generally bad in granting equity, and market outcomes may have undesirable distributional implications. In particular, intergenerational conflicts will not be solved in a perfect market economy. However, since the pioneering work of Güth et al. (1982) we know in particular that fairness considerations play a key role in the allocation of resources. Using insight from behavioral economics as established by Neilson (2006) as well as Fehr and Schmidt (2003) (for an overview, see Johansson-Stenmann and Konow, 2009), we argue that the issue of intergenerational fairness can explain, why in the past much too little was invested into climate change adaptation.[2] For example, if in the present the costs of adaptation exceed the benefits, the present generation has only little motivation for investing into adaptation, unless the future generation commits herself to compensate the present one for their adaptation expenditure. But why should the young generation donate something to the old one once the adaptation measure is implemented? This inconsistency phenomenon might explain why in many cases today too little is invested into public adaptation projects.

Section 2 presents an economic analysis based on a stylized model of overlapping generations with adaptation and discusses three stages of the world: first, where generations are motivated by self-interest only, second, in which intergenerational fairness considerations matter, and third, where the generations' behavior is characterized by altruism. It is shown that if generations decide solely in their own self-interest, too little will be invested into adaptation, while in a world, where intergenerational fairness matters, more will be invested into adaptation.

2. Model

Since the major purpose of this exercise is to provide inside from an economic perspective, ideas are presented in a simple way, by using a "stylized facts" model, which is deliberately simple, but general enough to convoy the central messages. Time is taken as discrete and agents are represented by a sequence of overlapping age cohorts. Each generation lives for two periods, the working period and retirement, and will be indexed by the date at which they enter the working period. Let y_t^1 denote conventional income of generation t, which in period t is in its first period of lifetime. y_t^2 denotes the income of generation t during retirement, which is its second period of life time. Note that for sake of simplicity income is taken as exogenously given.

Among the various greenhouse gases, carbon dioxide (CO_2) is the most relevant one and global climate change is directly attributed to cumulative CO_2-emissions. With the particular form of a public good model adopted here, global climate change affects income rather than utility. Consequently, depending on the stock Q_t of atmospheric carbon dioxide only a fraction $\emptyset_t$ of conventional income is at the generations' disposal for consumption. This means that economic costs of climate change are measured in terms of forgone conventional income due to global warming. The effects of global climate change on regional economies, however, can be moderated by investing into adaptation.

Adaptation comprises a variety of different measures, which are designed for improving the adaptive capacity of a society. Examples are investments into protection infrastructures such as dikes, early warning systems, or a change of urban architecture and building standards. But adaptation also includes changes in crops, seating, and harvesting times. To allow for such a heterogeneity, adaptation here is represented through expenditure. Therefore, the climate impact function[3] $\emptyset_t(Q_t, a_t)$, which expresses the fraction of conventional income that still is at the societies' disposal, is a concave function of the region's expenditure a_t for adapting to climate change as well as of the CO_2 concentration Q_t. This means, the higher the stock of globally accumulated greenhouse gas emissions and the less is invested into adaptation, the lower will be the fraction of income, which is at disposal for consumption. Or to phrase it differently, the more is invested into adaptation, the higher is the fraction of income at disposal, that is,

$$\partial\emptyset_t/\partial a_t > 0 \text{ with } \partial^2\emptyset_t/\partial a_t^2 < 0.$$

2.1. Self-interest only

Now, consider two adjunct generations $t, t+1$, and suppose that if at the beginning of period t the decision is made to invest into adaptation, climate protection will become effective from period $t+1$ onwards. Let a_t denote the investment expenditure and let $\theta(Q_{t+1}, a_t)$ be the remaining climate impact if a_t was invested into adaptation in period t.[4] If r denotes the market rate of interest, the present value[5] of green lifetime net income of generation t is given by

$$gy_t = \; y_t^1 - a_t + (1+r)^{-1}(\theta(Q_{t+1}, a_t)y_t^2). \tag{1}$$

Obviously, generation t will invest a_t into adaptation, if the green net present value of lifetime income gy_t with adaptation investments are at least as great as income without investments, that is,

$$gy_t \geq \; y_t^1 + (1+r)^{-1}(\theta(Q_{t+1}, 0)y_t^2).$$

Generation $t+1$ has the option to also invest into adaptation and hence has the green lifetime net income

[2]Note that we focus on issue of intergenerational equity by neglecting the important issue of intragenerational equity. Hoel et al. (2019) published a paper that deals with both aspects in case of mitigation, however.

[3]An example of a climate impact factor, which typically is used in integrated assessment analysis, is given by Manne et al. (1995) or Stephan and Müller-Fürstenberger (1998). Moreover, this function includes damages caused by flooding as special case, as Bosello et al. (2009) as well as Hoffmann and Stephan (2018) discuss in detail.

[4]For focusing on intergenerational fairness, let us sidestep the issue of uncertainty, by assuming that climate impacts are known for sure.

[5]It must be noted that using the market rate of interest for calculating present values implies a particular choice of a discount rate. The discount rate greatly affects the policy decision as was intensively discussed in the literature. For an example, see Arrow et al. (2013).

$$gy_{t+1} = \theta(Q_{t+1,}a_t)y_{t+1}^1 - a_{t+1} + (1+r)^{-1}\left(\theta(Q_{t+1}, a_t + a_{t+1})y_{t+1}^2\right). \quad (2)$$

Hence, since $\partial\emptyset/\partial a_t > 0$, investing into adaptation by generation t generates a positive external effect. Furthermore, by taking the total differential of (2) we get

$$\frac{da_{t+1}}{da_t} = -\frac{\partial\emptyset/\partial a_t y_{t+1}^1 + (1+r)^{-1}\partial\emptyset/\partial a_t y_{t+1}^2}{(1+r)^{-1}\partial\emptyset/\partial a_{t+1} y_{t+1}^2 - 1} < 0,$$

which is negative, since generation $t+1$ will invest additionally into adaptation only, if

$$(1+r)^{-1}\partial\emptyset/\partial a_{t+1} y_{t+1}^2 - 1 > 0.$$

This implies that the more the old generation has invested into adaptation, the lower are the optimal investments of the young generation.

Economic analysis usually employs the self-interest hypothesis, which means that actors are exclusively motivated by their material self-interest and do not consider the interests of the other agents when making decisions (see Fehr and Schmidt 2003). If we apply this assumption, this implies that generation t will invest only (see (1)), if

$$(1+r)^{-1}(\theta(Q_{t+1}, a_t)y_t^2 - (\theta(Q_{t+1}, 0)y_t^2)) \geq a_t. \quad (3)$$

Now suppose, however, that condition (3) does not hold true. Then given the structure of the problem, generation t has no incentive to invest into adaptation, unless generation $t+1$ is committed to transfer income. However, generation $t+1$ has no incentive to do so, since once it has to make its transfer decision the adaptation investment is already executed. Generation t anticipates this, and thus there will be a Pareto-inefficient outcome, where no investment takes place.

Alternatively, one could argue, generation t invests into adaptation as long as marginal income effects of investing into adaptation are non-negative, that is, $\partial gy_t/\partial a_t \geq 0$ or

$$(1+r) \leq \partial\emptyset_t/\partial a_t [y_t^2], \quad (3a)$$

which follows from condition (1).[6] There are two messages from condition (3a). First, an additional dollar will be spent for adaptation only, if the net return of this investment, and hence prevented damages $\partial\emptyset_t/\partial a_t [y_t^2]$, is at least as high as the net return from investing this dollar in the stock market. Second, conventional wealth matters. The higher the generation t's conventional income, the more will be invested into adaptation. As an outcome, this is consistent with the so-called Shelling conjecture (see Anthoff and Tol, 2011), but the reasoning is quite different. The Shelling conjecture says that highly developed, richer societies are less vulnerable, since they own the resources to invest into adaptation, while here net benefits of investing into adaptation simply exceed gains from saving.

2.2. Pareto improvements through transfers

Even if condition (3a) is satisfied, adaptation investment will not be Pareto-efficient. For Pareto efficiency requires that the welfare of both generations is maximized simultaneously, which leads to the following necessary condition of optimality:

$$(1+r) = \partial\emptyset_t/\partial a_t^* [y_t^2] + \partial\emptyset_{t+1}/\partial a_t^* y_{t+1}^2 + (1+r)\,\partial\emptyset_t/\partial a_t^* [y_{t+1}^1]. \quad (4)$$

where a_t^* denotes the Pareto efficient level of adaptation expenditure. This means that

$$(1+r) > \partial\emptyset_t/\partial a_t^* [y_t^2],$$

hence see condition (3a)

$$\partial\emptyset_t/\partial a_t > \partial\emptyset_t/\partial a_t^*$$

Which, because of concavity of the climate impact function $\emptyset_t(Q_t, a_t)$, implies $a_t^* > a_t$ higher investment compared to the case of pure self-interest.

The analysis so far is closely related to the one on fundamental standards and time consistency (see Konrad and Thum, 1993). As well as the work of Hoel et al (2019).[7] It reveals that in the absence of binding contracts the asymmetry of the distribution of costs and benefits of climate change adaptation will lead to an inefficient outcome as well as governmental failure in the following sense. Suppose there are two sovereign governments – one elected by the parents' generation and one by the descendants' generation. For internalizing the external effects of investing into adaptation, these governments have to write a contract, which foresees the investment into adaptation measures by the old generation on the one side and transfers from the young to the old on the other. But, once the adaptation measure is implemented, the descendants' government has an incentive to deviate unless institutions exist, which can enforce the contract.

Indeed, it is easy to show that intergenerational cooperation, for example, through transfer from the young to the old generation gives room for Pareto improvements. To see that suppose transfers T from the young generation is completely used for adaption investment. Then

$$gy_t(T) = y_t^1 - a_t + (1+r)^{-1}(\theta(Q_{t+1}, a_{t1} + T)y_t^2) \quad (1a)$$

Is the net lifetime income of generation t, which will raise, since $\partial\emptyset_t/\partial a_t > 0$. At the same time, lifetime income of generation $t+1$ will stay unchanged, if the transfer T equalizes the benefits from increasing adaptation in period t by T, and hence $\partial gy_{t+1}/\partial T = 0$, where

$$gy_{t+1}(T) = \theta(Q_{t+1,}a_t + T)y_{t+1}^1 - a_{t+1} - T + (1+r)^{-1}\left(\theta(Q_{t+1}, a_t + T + a_{t+1})y_{t+1}^2\right). \quad (2a)$$

2.3. Fairness considerations

How do fairness considerations change the analysis? To answer this question, let us use the approach proposed by Johansson-Stenmann and Konow (2009). Now suppose that the welfare U^t of generation t does not only depend on own lifetime income gy_t but also on the judgement of the distribution of income f^t across generations, which in turn depends on expected lifetime income, that is,

$$U^t = gy_t + f^t(gy_t, gy_{t+1}). \quad (5)$$

[6]Note that a necessary condition for optimal adaptation investment is $(1+r) = \partial\emptyset_t/\partial a_t [y_t^2]$.

[7]Hoel et al. (2019) consider mitigation and explore the idea that there is potentially some Pareto-inefficiency, due to missing options for intergenerational transfers.

Since green net income of both generations depends on adaptation investments a_t, utilities also depend on these, that is,

$$\frac{\partial U^t}{\partial a_t} = \frac{\partial gy_t}{\partial a_t} + \left(\frac{\partial f^t}{\partial gy_t} \frac{\partial gy_t}{\partial a_t} + \frac{\partial f^t}{\partial gy_{t+1}} \frac{\partial gy_{t+1}}{\partial a_t} \right). \quad (6)$$

The first expression on the right side indicates how utilities of generation t are affected through adaptation investments via changes in the generation's own green lifetime income. The second term shows the impact of fairness perception on the generation's welfare. The size of this effect depends on income effects on the one hand as well as by how much the fairness perception is affected by small income changes $\partial f^t / \partial gy_k,\ k = t, t+1$, on the other. Rearranging condition (6) gives

$$\frac{\partial U^t}{\partial a_t} = \frac{\partial gy_t}{\partial a_t} \left(1 + \frac{\partial f^t}{\partial gy_t} \right) + \left(\frac{\partial f^t}{\partial gy_{t+1}} \frac{\partial gy_{t+1}}{\partial a_t} \right),$$

which means even if the effect of adaptation on a generation's lifetime income is negative (i.e., $\frac{\partial gy_t}{\partial a_t} < 0$), it nevertheless could pay to invest into adaptation measures because of distributional effects. For providing a simple example, let us apply the utility function as has been established by Neilson (2006). Taken up for a two generations' case, the utility function is[8]

$$U^t = gy_t - \alpha(gy_t - gy_{t+1}) \text{ with } \alpha > 0. \quad (5a)$$

In words, this means: if compared to the future generation the present one is wealthier in terms of green net income, this negatively affects the welfare of the present generation.

From (5a), we observe

$$\frac{\partial U^t}{\partial a_t} = \frac{\partial gy_t}{\partial a_t}(1-\alpha) + \alpha \left(\frac{\partial gy_{t+1}}{\partial a_t} \right).$$

Hence, compared to the case of pure self-interest, this implies that a lower weight now is placed on changes of own green income, but a positive weight is put on the welfare effects of adaptation of the next generation. Therefore, since $\frac{\partial gy_{t+1}}{\partial a_t} > 0$ by definition, the impact of adaptation on welfare of generation t, $\frac{\partial U^t}{\partial a_t}$, could be positive, even if the effect on own net lifetime income $\frac{\partial gy_t}{\partial a_t}$ is negative, provided the fairness perception, that is, α, is high enough.

2.4. Altruism and bequest

Graham et al. (2017) show in an empirical study for the UK that for protecting against floods, the majority of voters selects policies, which bring equal or greater benefits to future generations. Only a minority selected a policy that most benefited their generation. Obviously, the behavior of the majority is characterized by altruism. Therefore, let us consider, how altruism affects adaptation decisions. Altruism in its most simple version means that parents care about the welfare of their children. Since welfare depends on income, there are two ways of affecting the welfare of the future generation, through investing into adaptation on the one hand and through bequest on the other. Let B denote the amount of income that is transferred, then one-sided intergenerational altruism changes the analysis as follows. Generation t now maximizes the present value of its own green income plus that of the income of the future generation. If W_{t+1} denotes the utility of generation $t+1$, which depends on green net income gy_{t+1} and bequest B this means:

$$Y_t^1 - a_t - B + (1+r)^{-1}(\theta(a_t)y_t^2) + W_{t+1}\left[\theta(a_t)y_{t+1}^1 + B - a_{t+1} + (1+r)^{-1}\left(\theta(a_t)y_{t+1}^2\right)\right].$$

By taking the partial differential with respect to a_t, the following necessary condition is observed:

$$(1+r) = (\theta'(a_t)[y_t^2]) + {dW_{t+1}}/{dgy_{t+1}}\left((1+r)\theta'(a_t)y_{t+1}^1 + \left(\theta'(a_t)y_{t+1}^2\right)\right). \quad (7)$$

which is a Solow–Stiglitz type of a condition. It says that in optimum generation t is indifferent between investing one unit of income into the financial market, which yields the income of $(1+r)$ or investing into adaptation, which generates marginal benefits as shown in the right side of equation (7). In other words, in optimum generation t is indifferent between investing into adaptation or into the financial market.

Furthermore, there is interaction between bequests and adaptation investment. By taking the total differential, we get

$$\frac{dB}{da_t} = -\frac{{\partial gy_t}/{\partial a_t} + \frac{dW_{t+1}}{dgy_{t+1}} {\partial gy_{t+1}}/{\partial a_t}}{\frac{dW_{t+1}}{dgy_{t+1}} - 1} < 0$$

which is negative, since there will be adaptation investment only if the numerator is non-negative and there will be bequest only, if $dW_{t+1}/\partial gy_{t+1} \geq 1$. This condition allows for two interpretations. First, if the old generation decides to invest into adaptation from which the young can profit, at the same time it decides to reduce bequests. And second, if bequest is reduced, then this loss in money transfer will be compensated through investing into adaptation. This motivates a policy intervention. Taxing bequest would rise the incentive to invest into adaptation.

3. Conclusions

Both in developing and in developed countries, the impact of global climate change is visible and tangible already. Nevertheless, investment in adaptation measures is far too low. Economist typically argues that this results from the fact that most adaptation measures have the features of a local public good. An alternative explanation, provided by lawyers mainly, is that the existing democratic institutions as well as legal regulations do not protect the interest of coming generations sufficiently (see Bertram, 2023).

We argue, however, that adaptation suffers, like mitigation, from severe time consistency problems. Since cost and benefits accrue at different points in time, this raises the question of intergenerational justice as political scientists point out (Page, 1999). With respect to our analysis, there is an important caveat, however. Our analysis is based on economic reasoning only and exhibits within a stylized overlapping generations model two major insights:

(1) In case of pure self-interest and without binding contracts, the asymmetry between the dates when costs and benefits of climate change adaptation materialize will lead to an inefficient outcome as well as governmental failure. The present generation invests in adaptation only if their own benefits of adaptation cover their costs. If this condition is not fulfilled, the future generation would have to

[8] Note, this example is a simplified version of preferences for fairness as developed by Fehr and Schmidt (2003). In a two person case, this type of an utility function has the form $U^t = gy_t - \alpha max\ (gy_t - gy_{t+1}, 0) - \beta max\ (gy_{t+1} - gy_t, 0)$, with $\alpha \geq \beta > 0$. The parameter β represents the disutility from allocations that are disadvantageously unequal for generation t due to envy about generation $t+1$'s higher payoff, while the parameter α captures the disutility from allocations that are advantageously unequal for generation t due to guilt over earning a higher payoff than generation $t+1$. Note that this kind of an utility function can explain voluntary contributions in public good games and costly punishment of free-riders (see Fehr and Schmidt, 2003)

commit herself to compensate the present one for parts of their adaptation expenditure. However, any promise made by the young generation is not reliable, since there is no need to donate to the old generation once the adaptation measure is implemented.

(2) Graham et al. (2017) show in an empirical study for the UK that for both saving lives and protecting against floods the majority of voters selects policies, which bring equal or greater benefits to future generations. Only a minority selected a policy that most benefited their generation. Obviously, this study raises questions about a core assumption of standard economic evaluation, pointing instead to concern for future generations as a value that many people hold in common.

Who benefits and who pays for adaptation are important intrinsically. But it is also important because if the burden of adaptation is perceived to be unfair, then action will not be legitimized, and interventions simply will not happen (see Davies, 2020). As our analysis reveals fairness considerations and altruism could indeed help to overcome the time consistency problem of adaptation. If the distribution of income between generations matters from the present generation's perspective and if the fairness perception is high enough, the impact of adaptation on welfare of these generation could be positive, although the effect on own net lifetime income may be negative. In other words, a responsible style of life pays off compared to a purely self-interest-oriented lifestyle. For in case of altruistic behavior, where each generation cares for the welfare of its subsequent generation by investing into either adaptation or conventional capital formation, in the resulting optimum more will be invested into adaptation.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

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