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# Climate Policies, Distributional Effects and Transfers Between Rich and Poor Countries[1]

Snorre Kverndokk[2]

ABSTRACT

This paper studies the role of equity preferences and distribution in climate policies by presenting mechanisms and results from dynamic North–South models. If policy makers express preferences regarding the distributive outcome of policies, they may adopt climate policies that influence the distribution in their preferred direction. A better distribution of outcomes may result even in the absence of such preferences if there exist strategic reasons for transfers from the rich to the poor countries. We also present results concerning when such transfers do and do not work according to policy makers' intentions. A transfer that proceeds from the poor to the rich countries is climate migration. This may have distributional consequences and possibly increase the incentives of the rich countries to implement climate policies that mitigate negative distributional effects, even if their main concern is with their own outcomes.

*Keywords:* Inter- and intragenerational equity, climate finance, migration, North–South models.

*JEL Classifications:* D63, D64, E22, H23, Q54.

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[2] Ragnar Frisch Centre for Economic Research, Gaustadalléen 21, 0349 Oslo, Norway. Email: snorre.kverndokk@frisch.uio.no.

# 1 Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992, with the aim of achieving the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC 1992). Since 1992, there have been ongoing negotiations attempting to reach a global agreement to achieve this goal. The first apparent sign of success was the Kyoto Protocol in 1997. However, it has not had any significant impact on climate change because its emissions reduction commitments applied only to developed countries, and there has been a considerable growth in emissions from countries that did not assume any commitments (International Energy Agency 2017). In addition, several major developed countries withdrew from the agreement.

However, a major step was taken in 2015 with the signing of the Paris Agreement. In contrast to the Kyoto Protocol, the Paris Agreement includes almost all countries in the world. Its aim is to avoid an increase in the average world temperature that exceeds two degrees Celsius. This is a concretization of the UNFCCC target from 1992 and was agreed upon during the climate negotiations in Cancun in 2010. Although the protocol is a significant step forward in the international climate negotiations, it has weaknesses. The commitments for all participating countries remain insufficient to meet the two-degree target (UNFCCC 2015),[3] which will be dependent on commitments being tightened in years to come.[4] Further, the national commitments are not binding because this would make it much harder to reach an agreement (Barrett 2005). Finally, in 2017, the President of the United States (US) withdrew the US from the Paris Agreement, reducing the amount of greenhouse gas (GHG) emissions covered by the protocol. Thus, whether the two-degree target can be met remains very uncertain.

Why is it so difficult for countries to reach a binding agreement to "prevent dangerous anthropogenic interference with the climate system", as specified by the UNFCCC? In addition to the well-known reasons studied in the economic literature, such as the public good nature of the environment (Hardin 1968) and free riding (Barrett 1994), a further answer relates to equity. Even if all countries agreed on the climate science, the feedbacks to the

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[3] Emissions in 2030 will be 37–52% higher than 1990 levels according to the UNFCCC (2015).

[4] According to IPCC (2014), this would require a 40–70% reduction in all GHGs by 2050, and no (or negative) emissions by 2100.

economy, the future emissions scenarios and the costs of abatement (i.e., if there were no uncertainties), it would still be hard to agree on the optimal global GHG emissions reductions and how they should be distributed among countries.[5] In particular, equity aspects are important in climate policy for several reasons.

First, optimal emissions reductions depend on ethical considerations. Thus, even without any uncertainty, people and governments would not necessarily agree on the optimal reductions. One example of this is the different emissions reductions that arise from the global integrated assessment models. These models use different ethical parameters, such as the social discount rate and the concavity of the utility function, and, therefore, their answers to the question of optimal mitigation vary (Nordhaus 2008, Chapter 9).

Second, treaties that are considered unfair may be hard to implement even if they are profitable. For example, this is evident from the lessons from ultimatum games (Oosterbeek et al. 2004). These games involve two players, where the first player receives a sum of money and proposes a distribution of the sum between the players. If the second player accepts this distribution, the money is split accordingly. However, if the second player does not accept, neither player receives any money. Very often, the second player refuses a distribution that is considered unfair even if the alternative yields a worse outcome.[6] In climate change negotiations, this could mean that countries may not sign an agreement that they consider unfair, even if this could lead to failure of the treaty, an outcome that would be worse for all.

This paper examines equity issues and provides a survey of studies in the economic literature that examine the impact of the distributional effects of climate policies in rich and poor countries. It is related to other surveys on climate policy and equity published in the *International Review of Environmental and Resource Economics*, including Kverndokk and Rose (2008) and Pottier et al. (2017), but we have a narrower focus than these papers.[7] In particular, we focus on dynamic North–South models and how social preferences and transfers in climate policies affect economic variables such as welfare, economic growth,

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[5] The US President argued that “the bottom line is that the Paris Accord is very unfair, at the highest level, to the United States” when announcing that the US would withdraw from the Paris Agreement; see https://www.whitehouse.gov/briefings-statements/statement-president-trump-paris-climate-accord/.

[6] Such Pareto-damaging behavior may be the result of reciprocity (Rabin 1993), whereby people punish what they consider unfair behavior by the other player.

[7] See Kolstad et al. (2014) and Stern (2014a,b) for further discussions of the ethical dimensions of climate change.

capital accumulation and emissions. We do not attempt to fully cover the existing literature, but rather concentrate on some studies that provide examples of important mechanisms.

Distribution is central in the equity debate. What is a fair distribution of emissions reductions? Should all countries mitigate their emissions, or only those that are historically responsible for the bulk of the warming that we have begun to notice? Should only the countries that can afford to do so mitigate emissions, or should all countries contribute? The answers to such questions depend on the equity principle that one applies. Even if equity principles serve as focal points that can reduce negotiation costs (Schelling 1960), they may be affected by the position and situation of the negotiators, as a (thick) “veil of ignorance” (Rawls 1971) does not exists in climate negotiations. This will be further discussed in Section 2, where we provide a brief discussion of equity principles in climate policy.

Equity questions in international climate negotiations are often related to the different situations of rich and poor countries. Rich and poor countries will be affected differently by climate change, as both the temperature level and the level of development matter in terms of the impacts of climate change on an economy. For example, Burke et al. (2015) show that the average annual temperature has an effect on economic production, using data for 166 countries over the period 1960–2010. Productivity improves as annual temperature increases up to an optimum of about 13 °C, but declines with a warmer climate, and the decline accelerates the warmer it becomes. Most developed countries have average temperatures of around 13 °C or lower, whereas developing countries mainly have higher average temperatures and, therefore, will be more severely affected in economic terms by climate change. Mitigation costs will also differ between rich and poor countries (Kverndokk and Rose 2008). Cheap mitigation options are mainly found outside the OECD countries because non-OECD countries have lower energy efficiency (Geller et al. 2006; Zhang et al. 2011). However, the opportunity cost of mitigation may be higher in poor countries because GHG mitigation may reduce or hamper economic growth and negatively impact poverty reduction and social welfare.

Mitigation costs and the impacts of climate change have implications for the climate policy of a country, but the optimal strategies of countries and governments also depend on their ethical considerations. What is optimal depends on the preferences of the agent (e.g., one country). If the agent had social preferences, that is, if it cared about the outcomes of other agents (e.g., other countries), the strategies adopted would be different from those if the agent cared only about its own outcome. This issue will be discussed in Section 3, where we provide examples of how inequality aversion is introduced in models of climate policy and study how equity preferences can affect economic growth, capital accumulation and emissions.

As discussed above, climate policies are not only about efficiency, but also about distribution. In economic thinking, efficiency and distribution are separate problems that, ideally, should be solved by separate policy measures; for example, carbon pricing may result in an efficient outcome, with transfers from rich to poor countries to solve the distributional issues. However, the policy measures at hand may not be able to solve the large inequalities that arise from the impacts of climate policies and climate change around the world, and we do not have time to solve the large existing inequalities before we attempt to reduce the climate problem. Therefore, distributional impacts may matter for the choice of climate policies. This is also reflected in the UNFCCC's principle of "common but differentiated responsibilities and respective capabilities" (UNFCCC 1992).

This does not mean that transfers from rich to poor countries should not play a role in climate policies; indeed, transfers are a part of the UNFCCC. As stated in the Copenhagen Accord of 2009 (UNFCCC 2010), and reaffirmed in subsequent negotiation documents, developed countries have promised to provide climate finance of up to $100 billion a year from 2020 to help developing countries reduce their emissions and adapt to climate change. In Section 4, we study the effect of such transfers. We first focus on transfers to poor countries, such as mitigation transfers, adaptation transfers and development aid. However, one transfer, climate migration, proceeds in the other direction, from poor to rich countries, and the impacts of such transfers are also surveyed.

## 2 Equity Principles in Climate Policy

In this paper, we define equity as *distributive justice*, meaning that we consider the distribution of goods and burdens or costs and benefits among agents (Paterson 2001). Further, we distinguish two dimensions of equity, namely *intragenerational* and *intergenerational* equity; see e.g., Kverndokk et al. (2014). Intragenerational equity mainly concerns how we should distribute the burdens within a generation, either within the generation living today or within future generations (Kverndokk and Rose 2008). Conversely, intergenerational equity is about how we should distribute burdens across generations.

Most economic studies treat these equity dimensions separately. However, Heal (2009) points out that the two dimensions of equity are connected. Choices that affect the intergenerational distribution have impacts on the intragenerational distribution and vice versa. Two examples illustrate this interconnection. A high discount rate based on intergenerational concerns reduces mitigation action and increases climate damage. As a result, in the future, it is likely that poor regions will suffer more than rich regions, which results in higher intragenerational inequality. On the other hand, lowering global income inequality today may induce higher economic growth in the poor countries. This may result in higher GHG emissions and a greater negative impact on future generations. Thus, there seems to be a trade-off between intra- and intergenerational equity in climate policies, which we will study in Section 3.2.

### *2.1 The Choice of an Equity Principle*

Equity is a major criterion on which to base policies (Rawls 1971). However, although Pareto optimality is an accepted efficiency principle, there is no consensus on the “best” equity principle (Kverndokk 1995 provides further discussion). An equity principle determines how to share burdens either within or across generations. Many equity principles have been put forward; for an overview of such principles in climate policies, see Paterson (2001) and Kverndokk and Rose (2008).

Although equity principles may serve as focal points, individuals or countries do not necessarily support the same equity principles. One reason for this is that equity principles may be used strategically depending on the situation. Examples of this in the case of principles for intragenerational justice are found in Lange et al. (2007; 2010). Both studies are based on data from a worldwide survey of people involved in climate policy making. The following six equity principles are considered:

- **The egalitarian rule**: a country with a population that amounts to x% of the global population should receive x% of the global entitlements for GHG emissions.
- **The sovereignty rule**: a country with GHG emissions that amount to x% of the global GHG emissions should obtain x% of the global entitlements for GHG emissions.

- **The polluter-pays rule**: a country with GHG emissions that amount to x% of the global emissions should bear x% of the global abatement costs.
- **The ability-to-pay rule**: a country with GDP amounting to x% of global GDP should bear x% of the global abatement costs.
- **The poor losers rule**: poor countries are exempt from obligations.
- **The stand-alone rule**: there should be no excessive emissions entitlements (no hot air).

Lange et al. (2007) find that equity issues are considered highly important in international climate negotiations; however, they are seen as more important by respondents from poor countries. Regarding differences in support for the different principles, individuals from rich countries are less in favor of the polluter-pays and the ability-to-pay principles. The poor losers rule is more strongly supported by individuals from poor countries. These results are compatible with pure economic self-interest. However, in the long run, respondents from rich countries are more in favor of the egalitarian principle, which actually goes against their pure economic interests. This strengthens the possibility that in agreements with long-run goals, equity issues may not be determined by self-interest alone.

Lange et al. (2010) use the same survey as Lange et al. (2007), but also consider economic mitigation cost estimates derived from the POLES (Prospective Outlook on Long-term Energy Systems) model (Criqui et al. 1999) to study arguments regarding the self-interested use of equity rules. They find that the support for different equity rules in different regions may be explained by the ranking of the economic costs of the equity rules. Thus, support for an equity criterion is stronger the less costly it is and, therefore, equity criteria may be used strategically.

Then, we ask, should we model equity in economic models studying climate policy? If policy makers have equity preferences and care about the distribution of costs and benefits, it would be wrong to ignore this in models of international climate policies, especially if these preferences affect outcomes. As argued in the Introduction, this is particularly important when international transfers cannot eliminate inequalities arising from climate action or inaction.

## 3 Equity Preferences in Economic Models of Climate Policies

A global social planner may have normative preferences in line with the equity principles discussed above. However, for an agent of a country or region, equity preferences are often presented as social preferences, such as preferences about distributions of outcomes. Thus, the local planner may make decisions based on the best response of other planners or in negotiations with other planners. In Sections 3 and 4, we provide examples of how equity preferences have been introduced in economic models of international climate policies, where the main focus is on local planners.

### *3.1 Inequality Aversion as a Social Preference*

Inequality is an important aspect of distributive justice. People may express preferences for equality and dislike inequality. This may result in a trade-off between efficiency and inequality, and studies focusing on this reach differing conclusions. Whereas Charness and Rabin (2002) find that subjects often sacrifice equality for increased efficiency, Bolton and Ockenfels (2000) report a relatively low willingness to pay for efficiency. The dislike of inequality is often termed inequality aversion. There are three main models dealing with inequality aversion, by Fehr and Schmidt (1999), Bolton and Ockenfels (2000) and Charness and Rabin (2002).

First, the most general approach is by Charness and Rabin (2002), who present a model of social preferences that covers reciprocity, distributional preferences (such as competitive behavior and inequality aversion) and Pareto optimality, i.e., social welfare maximization. For instance, Kolstad (2011) applies Charness–Rabin preferences to climate policies to study coalitions in public goods provision.

Second, Bolton and Ockenfels (2000) present a theory of inequality aversion based on the assumption that the relative rather than the absolute inequality of payoffs matters for individuals. There are some applications of this model in the climate policy literature, such as Lange and Vogt (2003) and Lange (2006), who apply these preferences to study coalition formation in international climate negotiations.

Finally, Fehr and Schmidt (1999) assume that people enjoy utility from a high payoff ($x$) but also have preferences for the distribution of payoffs, such that although they dislike having higher payoffs than others, they dislike having lower payoffs than others even more. Inequality is defined as the absolute difference between outcomes. In a model of *n* individuals, this is expressed as:

$$(1) \qquad U_i(x) = x_i - \alpha_i \frac{1}{n-1} \sum_{j \neq i} \max\left[x_j - x_i, 0\right] - \beta_i \frac{1}{n-1} \sum_{j \neq i} \max\left[x_i - x_j, 0\right],$$

where $\beta_i \leq \alpha_i$ and $0 \leq \beta_i < 1$.

The Fehr and Schmidt framework has been used primarily to describe preferences for income equality among individuals. However, in the past few years, it has also been used to study the social preferences of climate policy makers in different regions. Dannenberg et al. (2010) measure inequality aversion empirically among participants in climate negotiations from different countries. The authors use experimental games to test the model of Fehr and Schmidt (1999). They find that the participants dislike, to a considerable extent, being better off than others, whereas their aversion to being worse off than others is moderate, i.e., $\beta > \alpha$, which contrasts with the assumptions by Fehr and Schmidt. They do not find significant differences between individuals from different regions of the world in their experiments. Therefore, they conclude that differences in climate policy are more likely to be caused by national interests.

### *3.1.1 An Application of Fehr–Schmidt Preferences*

Kverndokk et al. (2014) use the Fehr–Schmidt preferences to model optimal climate policies and the implications for production and consumption patterns in a North–South model. The regions express inequality aversion in the context of intragenerational outcomes, where inequality is defined as the difference in consumption levels per capita, *c*. Therefore, the welfare of a representative consumer in region *r*, where the population is set equal to one in both regions, is:

$$(2) \qquad U_{r,t} = u\left(c_{r,t}, S_t\right) - \alpha \max\left(c_{k,t} - c_{r,t}, 0\right) - \beta \max\left(c_{r,t} - c_{k,t}, 0\right), \;\; r,k = n,s, \;\; r \neq k,$$

where $\alpha \geq \beta \geq 0$, $n$ is North and $s$ is South.[8] Further, $S$ is the global environmental quality (climate), which decreases with GHG emissions, and it is assumed that consumption and environmental quality are complements in the utility functions, $u(\cdot)$.

The production of a macro good follows from the production functions:

$$(3) \qquad Y(K_{r,c,t}, K_{r,d,t}) = Y_c(K_{r,c,t}) + Y_d(K_{r,d,t}), \quad r = n, s,$$

where there is a clean input ($Y_{r,c,t}$) and a dirty input ($Y_{r,d,t}$) that are perfect substitutes in the production process. The clean input is produced by clean capital ($K_c$) and the dirty input is produced by dirty capital ($K_d$). The difference between the North and South is that the North initially has more of both types of capital stocks compared with the South. Pollution follows from the use of dirty capital, and so the quality of the global environment, $S$, decreases with its use. Capital stocks increase with investment and decrease with depreciation. Based on this, the macro good can be used for consumption and investment in the two capital stocks. There are no transfers between regions.

A social contract is defined as the outcome of the maximization of the present value of the sum of welfare in the two regions:

$$(4) \qquad \max_{\{c_{n,t}, c_{s,t}, K_{n,c,t+1}, K_{s,c,t+1}, K_{n,d,t+1}, K_{s,d,t+1}, S_{t+1}\}} \sum_{t=0}^{\infty} \rho^t \left\{ \sum_r u\left(c_{r,t}, S_t\right) - \phi \max\left(c_{n,t} - c_{s,t}, 0\right) - \phi \max\left(c_{s,t} - c_{n,t}, 0\right) \right\}.$$

Here, the intergenerational equity aspect is taken into account by the choice of the utility discount rate ($\rho$). Note also that $\phi \equiv \alpha + \beta$.

In the long run, the socially optimal consumption levels and capital stocks of the two regions will converge independently of inequality aversion, owing to the diminishing marginal utility of consumption and declining marginal productivity. Note that for investments in dirty capital to be socially optimal, their marginal productivity must be higher than that of clean capital, because it also has to cover the social cost of carbon. This means that the productivity of dirty

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[8] This assumption follows Fehr and Schmidt (1999), but contrasts with the result from Dannenberg et al. (2010). However, this does not have any implications for the analyses below.

capital is higher in the South than in the North when there are diminishing returns to scale, as the stock of dirty capital is higher in the North than the South.

While the results are independent of inequality aversion in the long run, intragenerational preferences have impacts on climate policy in the short and medium term. Note that the North affects the South through its consumption and pollution. The presence of inequality aversion will generally increase consumption in the South and reduce consumption in the North compared with the case with no such aversion. As there are no transfers, this can be achieved in the short run by higher investments in the North and/or lower investments in the South (of either type). However, there is a trade-off between inequality now and later. Inequality aversion may increase consumption inequality in some later periods, as the high investments in the North increase its productive capacity, which, at some point, will be optimal to use for consumption. When this will occur depends on the time preference rate. The less weight that we place on future generations relative to those living today, the stronger is the incentive to immediately eliminate inequality today through investments. However, the only way to achieve equity after some time is by shifting investments toward clean capital in the North, as this is less productive, and toward the more productive dirty capital in the South.

Inequality aversion does not affect the environment in the long run, as the steady-state capital stocks are independent of inequality aversion. However, in the short run, the impacts are ambiguous, as the dirty capital stocks are lower in the North and higher in the South compared with the case of no inequality aversion. Thus, if we care about equality, we may have to sacrifice the environment in the short run to allow the poor region to grow faster and pollute more.

Without a social contract, each country perceives its impact on the dynamics of global environmental quality as approximately zero. This is called the business as usual (BAU) case. In this case, there is still a convergence of consumption and capital stocks that is independent of inequality aversion. However, the dirty technology does not have to be more productive than the clean technology, as the social costs of pollution are not taken into account.

Under BAU, the North can no longer affect the marginal utility of the South, as each country takes the quality of the environment as given. The only possibility for the North to reduce inequality is to reduce consumption. This would lead to higher accumulation of both types of capital, as there is no reason to transition toward clean capital. As in the social contract, at some stage, the higher capital in the North has to be consumed and lead to a temporary increase in consumption. For the South, the opposite effects occur. Thus, inequality aversion generally increases emissions in the North and reduces emissions in the South.

If we compare BAU with the social contract case, there are two differences. In BAU, the representative consumers do not take into account the effects of their decisions on the global environment or on the other region's inequality aversion (i.e., the other region dislikes inequality). The first issue represents an environmental externality, whereas the second involves a consumption externality. These externalities are taken into account in the social contract case. For the North, when these externalities are not taken into account, there is less incentive to reduce consumption in BAU, and there will be more dirty production. However, for the South, there will be two opposing incentives. When the consumption externality is not taken into account, there is a lower incentive for dirty production in BAU, as the South does not care about the benefit that rich countries obtain from lower inequality. On the other hand, not taking the environmental externality into account means that there is a higher incentive for dirty production in BAU. This means that, under the social contract, the stock of dirty capital will be lower in the North, but not necessarily in the South. Thus, inequality aversion will mean there is a reduction in emissions in the North under the social contract compared with BAU, whereas the result for the South is ambiguous. Therefore, the South could be allowed to increase emissions under the social contract.

### ***3.2 The Use of Other Social Preferences in Climate Models***

Other social preferences are used in the economic literature on climate policies. Anthoff and Tol (2010) present a range of such preferences and study their impact on the social cost of carbon. They note *sovereignty* preferences, which they define as occurring when countries are concerned only about their own consumption levels and ignore broader impacts, such as GHG emissions.[9] In addition, Anthoff and Tol examine the following social preferences.

A local social planner, such as the government of a country, is defined as being *altruistic* toward people abroad when it has the following intertemporal welfare function:

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[9] The concept of *sovereignty* is defined differently here than in Section 2.

(5) $$w^a\left(c_t,c_{t,i}\right)=\left[\sum_{t=0}^{T}u(c_t)P_t(1+\rho)^{-1}\right]+\left[\sum_{t=0}^{T}\sum_{i=1}^{N}u^*(c_{t,i})P_{t,i}(1+\rho)^{-1}\right].$$

Welfare is the sum of the present value of the country's own utility ($u$) and of all foreign countries' utility functions ($N$) valued by the domestic planner ($u^*$). $c_t$ is defined as average per capita consumption in the domestic country at time $t$, and $c_{t,i}$ is the average per capita consumption of the foreign country $i$ at time $t$.[10] $P$ is the population size and $\rho$ represents the time preferences. Based on this welfare function, the social planner cares about the welfare of the other countries, in addition to the negative impacts of its domestic policies abroad, such as GHG emissions.

A social planner is *a good neighbor* if it cares about harm imposed on others, as follows:

(6) $$w^n\left(c_t,c_{t,i}\right)=\left[\sum_{t=0}^{T}u(c_t)P_t(1+\rho)^{-1}\right]-\left[\sum_{t=0}^{T}\sum_{i=1}^{N}\Delta u_{t,i}P_{t,i}(1+\rho)^{-1}\right],$$

where $\Delta u$ is the damage done abroad by domestic action, expressed as a reduced per capita utility, i.e., the difference in utility without and with the domestic emissions. It is assumed that compensation is not possible. Instead, the social planner takes into account the damage imposed on other regions when deciding the domestic consumption level and, therefore, domestic GHG emissions.

In the final specification, *impacts abroad are compensated*. This can be thought of as a treaty, under which countries have an obligation to compensate harm imposed on other countries. If $L_i$ is compensation paid to country $i$ and $L^*$ is the sum of compensation received from other countries, the intertemporal welfare function of a country is as follows:

(7) $$w^c\left(c_t,\mathrm{L}_t^*,\mathrm{L}_{t,i}\right)=\sum_{t=0}^{T}u\left(c_t+\frac{L_t^*-\sum_{i=1}^{N}L_{t,i}}{P_t}\right)P_t(1+\rho)^{-t}.$$

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[10] Note that $c_{t,i}$ is a vector on the left-hand side of the equation. Similar notation is used in the equations below.

Anthoff and Tol (2010) use these specifications in the FUND (The Climate Framework for Uncertainty, Negotiation and Distribution) model to find the social cost of carbon or the optimal carbon tax. They show that the different welfare functions give rise to totally different optimal carbon taxes and, therefore, different climate policies for a region. Not surprisingly, they find that the carbon taxes are lowest in the *sovereignty* case, i.e., when policy makers do not care about the impacts on others. In contrast, the tax is highest in the *good neighbor* case for rich countries, with compulsory *compensation* for the poor countries. This shows that the equity preferences of a country matter for the climate policies of a region and that, if countries have different equity preferences, they will argue for different climate policies in international negotiations.

### *3.2.1 The Pareto Improvement Principle*

Now, we turn to an equity principle called the *Pareto improvement principle* (Foley 2009 provides a good introduction to this principle). The starting point for this principle is that significant climate change is caused by a market failure, and correction of this failure will yield a Pareto improvement. Thus, it should be possible for a global or local planner to design an international treaty where no generation loses, but this would involve a transfer from the future generation to the present generation, as the present generation will need to bear the costs of mitigation to reduce future climate change for the benefit of those living in the future.

To explain this, assume that both generations gain utility from consumption, $C$. The consumption levels are functions of two types of capital stocks, conventional capital, $K$, and environmental capital, $E$. The latter is capital that reduces the stock of GHGs in the atmosphere as a result of mitigation.

The present generation faces the following resource constraint:

$$(8) \qquad Y = C + I_K + I_E,$$

where $Y$ is production and $I_K$ and $I_E$ are investments in $K$ and $E$, respectively. The future generation will benefit from both more conventional capital and a better environment, such that investing in both capital stocks will increase its consumption level.

Foley (2009) argues that, within this framework, the present generation will not necessarily lose from mitigating climate change, especially if the present generation reduces investments in $K$ to free resources for investments in $E$. In this way, the present generation can maintain its consumption level, even if it increases mitigation. Whether this is beneficial for the future generation depends on the marginal value of a lower stock of atmospheric GHGs compared with an increase in conventional capital. If the future generation values a better climate more than an increase in conventional capital, it would be optimal for the future generation if the present generation changes its investments from $K$ to $E$. One way of doing this is to borrow abroad to finance mitigation.[11] This may protect the present generation's consumption level and, at the same time, drive up the interest rate, which will reduce investments in conventional capital. In this framework, the discount rate is not directly important for the mitigation level, but it will determine the distribution of the additional consumption that arises from correcting the inefficiency between present and future generations.

Rezai et al. (2012) have a different view on Pareto-improving mitigation. They claim that the BAU scenario in a typical integrated assessment model is a hybrid: it takes into account the effect that the GHG concentration in the atmosphere has on future production possibilities, but still sets mitigation to zero. Thus, it is a constrained optimum. This lowers the return on conventional capital in the future and therefore reduces investments and increases current consumption. Using a BAU scenario where the agent did not take into account GHG accumulation at all would increase capital accumulation and reduce current consumption. Thus, the fall in current consumption from the optimal policy will be reduced in this BAU scenario compared with the constrained optimum, and may even be eliminated. If it is eliminated, there may be a Pareto improvement.

Hoel et al. (2018) further examine the Pareto-improving criterion explained by Foley (2009), but study it in a North–South model and, therefore, extend it to take into account both the intergenerational and intragenerational aspects of a Pareto-improving climate agreement. They present a two-period, two-region integrated assessment model, in which production will increase with a higher capital stock, but also with emissions, because polluting input factors are used. The available output will differ from production, as it will fall with accumulated

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[11] See, for instance, Bovenberg and Heijdra (1998), who examined Pareto-improving mitigation when compensation is achieved by a government that borrows in foreign capital markets and repays the debt by taxing future generations.

GHGs in the atmosphere. The welfare of a generation or a region follows from their consumption level. The only way that the present generation can affect the welfare of the future generation is through real investments and emission reductions. Investments will increase the capital stock and, therefore, the productive capacity of the future generation, whereas lower emissions will reduce the damage, defined as output lost.

In the BAU scenario, the regions will not take into account the negative externalities from their use of polluting inputs in the production process, and the social optimum is defined as the outcome from maximizing the present value of the (weighted) sum of the regions' utility functions. In contrast, we define a Pareto-improving agreement in the following way. Let $\bar{U}_t^k$ be the utility in the BAU scenario of region *k*, at time period *t*. A Pareto-improving climate policy has to satisfy $u(C_t^k) \geq \bar{U}_t^k$ for all time periods *t* and all regions *k*, where $C_t$ is the consumption level. Thus, a Pareto-improving agreement is the outcome of maximizing the present value of the weighted sum of the utility functions, given the restrictions on the utility levels.

To illustrate this, consider the case where transfers between regions ($k = a,b$) within the same time period are possible, $t = 1,2$. Now, all Pareto-efficient outcomes have the property that $C_2^a + C_2^b$ is maximized for any given value of $C_1^a + C_1^b$. In Figure 1, the Pareto-efficient frontier is drawn. Let *M* be the social optimum and *N* the BAU case. As shown, the social optimum is Pareto efficient, but it is not on the Pareto-improving frontier, which is the line between *P* and *Q*. A Pareto-improving agreement with consumption transfers must be on this line.

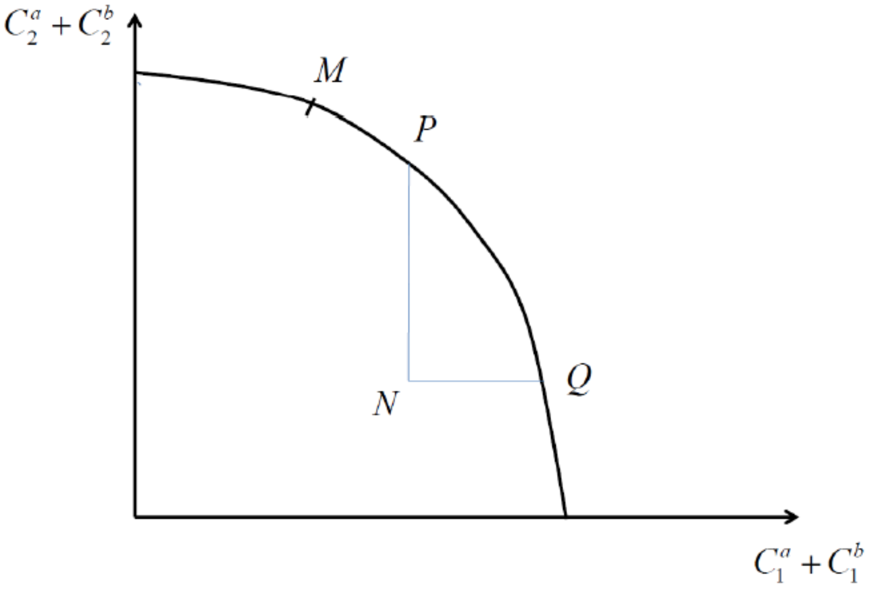

**Figure 1:** An illustration of Pareto-optimal deviations from the BAU case

Would a Pareto-improving agreement result in higher or lower emissions than the social optimum? Moving up and to the left on the frontier, i.e., closer to *M*, means that consumption falls in the first period. In the model, this can be achieved with higher investments and/or lower emissions. For declining returns on both investments, we may expect both effects to occur. Thus, Pareto-improving policies may result in higher emissions than the social optimum.

To study this issue more closely, the authors use simulations with a regionalized version (RICE) of the Dynamic Integrated model of Climate and the Economy (DICE), see e.g., Nordhaus (2008). Simulations show that when consumption transfers are possible, Pareto-improving policies result in higher emissions than the social optimum and, therefore, higher temperature paths, which confirms the intuition from the graph above. However, when transfers are not possible, emissions paths can be lower than in the social optimum, at least for a period of time, if the rich regions receive the gains. In this case, the only possibility for a region to influence the consumption of other regions is through the environment. Thus, climate policy can be used as a redistributional instrument as more abatement needs to occur to satisfy the distributional requirements.

# 4 Transfers Between Rich and Poor Countries

So far, transfers between rich and poor countries have been studied only briefly. Transfers are likely to play an important role in future climate policies, as they are part of the UNFCCC. Rich countries have agreed to the provision of climate finance to poor countries, meaning that they should provide financial resources to support developing countries to undertake mitigation and adaptation activities. This is also made clear in Article 4 in the convention, which includes an explicit commitment to promote technology diffusion internationally.

There are several reasons why transfers can be justified. First, as argued in the Introduction, transfers can be used to separate efficiency and distributional considerations. When this policy instrument is available, an emissions reduction target can be reached with less use of resources than when transfers are not possible, as negative distributional impacts can be compensated. In addition, transfers play a role in ensuring the distribution of income or welfare accords with a preferred social outcome, even when efficiency considerations are not the main focus. People in developed countries may care about the welfare of people in developing countries and, therefore, transfer resources to them (Eyckmans et al. 2016). Transfers may also follow from a retributive justice perspective, whereby “those who cause the problem have the responsibility to make amends for it” (Paterson 2001, p. 121). As rich countries are responsible for the major part of historical GHG emissions, they are responsible for most of the global warming that the world is experiencing and will experience in the near future. Thus, transfers from rich to poor countries may be justified as compensation on this basis; see also Meyer and Roser (2010).

However, most of the economic literature focuses on the strategic value of transfers. The majority of the new technologies developed to reduce emissions have been made in the developed world, and a massive transfer of this technology is necessary to meet the two-degree target because most of the growth in $CO_2$ emissions is expected to be caused by the developing countries (Dechezleprêtre et al. 2011). The early literature in the field focused on the role of transfers in making a limited climate treaty significant. Carraro and Siniscalco (1993) and Kverndokk (1994) argue that side payments, mainly from OECD countries to non-OECD countries, would be an effective policy instrument in this respect. Barrett (2003 2007), Eyckmans and Tulkens (2003), Aronsson et al. (2010) and Hong and Karp (2012) focus on using transfers to form and secure an international environmental agreement or to improve welfare in both regions. Transfers can also be used to reduce carbon leakage, as shown by Hoel (2001) and Golombek and Hoel (2004). Carbon leakages may follow from mitigation by one country or a group of countries. Mitigation may reduce demand in the country undertaking mitigation actions and, therefore, reduce the price of polluting energy goods, which may lead to higher demand for such goods by countries not taking action to mitigate. Thus, part of the emissions reduction can be offset. However, properly designed transfers and technology diffusion may reduce this carbon leakage and can, therefore, be beneficial for the mitigating countries. Another strategic reason for giving transfers to poor countries is to expand the market for trade. For instance, by transferring technology, the demand for services and goods connected to this technology may increase in the future.

Below, we examine transfers of different types from rich to poor countries and study how they change the incentives for climate policies, as well as how they affect economic growth and GHG emissions. In particular, we investigate technology transfers for both mitigation and adaptation, and development aid. As shown, some of these transfers operate as pure income transfers, and we study the effect of such transfers. Finally, we also consider climate migration transfers. This type of transfer differs in that the transfer proceeds from poor to rich countries and involves people, not technology or money. We do not attempt to provide a full review of climate policy transfers, but focus on some theoretical studies that demonstrate important mechanisms. Popp (2011) provides a broader review of technology transfers in international climate policy.

### *4.1 Mitigation Transfers*

Mitigation transfers could come in the form of mitigation technology or as money earmarked for mitigation measures. The simplest model to study mitigation transfers from rich to poor countries is presented by Yang (1999). In his North–South model, it is in the North's interest to reduce emissions because they contribute negatively to income and, thus, utility. However, the climate is a public good because it is affected negatively by the sum of emissions from the North and the South. Thus, it does not matter for the North if the emissions reductions come from the North or the South. However, the South is assumed to be on its optimal path with no intention to reduce emissions, so it will not mitigate unless the North makes it cheaper for it to do so. Then, the North faces the following decision problem: should it transfer mitigation technology to the South to make it mitigate, and, if so, how much?

This decision, in the form of an optimal path of transfers, is the solution to the following dynamic optimization problem, where superscript *N* stands for North:

$$(9) \qquad \max_{I^N, Tr, J} \int_0^\infty U^N\left(F^N\left(K^N(t)\right) - I^N(t) - Tr(t) - J(t), -\mathrm{B(t)}\right) e^{-\rho t} \ .$$

Thus, the North wants to maximize the present value of its utility (*U*), which is a function of consumption and the state of the environment (*B*). Consumption is defined as income (*F*) less expenditure on investments (*I*), mitigation transfers to the South (*Tr*) and mitigation costs in its own region (*J*). Income follows from production, where capital (*K*) is the input factor.

There are two state variables in the model: capital, which increases with investments and decreases with depreciation; and the state of the environment, defined as the carbon concentration in the atmosphere. A higher concentration yields a lower utility level. The concentration increases with emissions from the North (*h*) and the South (*G*), and decreases with depreciation. Further, emissions in the North arise from the use of capital and decrease with mitigation costs, whereas emissions in the South decrease with transfers, but increase exogenously over time without the transfers. That is, we have:

$$(10) \qquad \dot{B}(t) = h\left(J(t), K^N(t)\right) + G\left(Tr(t), t\right) - \sigma B(t) \ .$$

Unilateral transfers from the North to the South follow from pure self-interest, in that they increase the utility of the North. In this setting, mitigation at home and technology transfers are substitutes, as both contribute to a better environment. Thus, not surprisingly, the optimal solution is that the marginal benefit of a dollar spent on mitigation at home should equal the marginal benefit of mitigation abroad (i.e., transferring mitigation technology) at each point of time. The North may mitigate at home and transfer mitigation technology to the South, but there may be a corner solution where only transfers are made, and the South does all the mitigation, or where transfers are not optimal because mitigation in the South is too expensive.[12]

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[12] The model is supplemented with simulations using the RICE model. These simulations show that transfers will typically increase over time, as there is an exogenous increasing trend in the BAU emissions from the South.

This simple model illustrates that technology transfers may secure an international treaty, because emissions reduction in poor countries is possible with sufficient transfers of mitigation technology from rich countries. This may be in the interest of the rich countries if it is cheaper to reduce emissions in the poor countries, but the South will also benefit from it in terms of welfare. Even if there is no treaty, a group of countries or a large country may find it beneficial to promote abatement in other countries by transferring mitigation technology. This is an important result, and different versions of it appear in other studies referred to in the introduction of Section 4. However, as we will show below, the result does not always hold: transfers may have a negative impact on the environment and they may reduce the incentives for mitigation in the poor region.

### *4.1.1 Negative Environmental Impacts of Transfers*

Below, we will study two examples where a mitigation technology transfer may result in negative impacts on the environment. In both cases, the transfer makes the poor region (the South) more effective in producing polluting goods and, therefore, increases its production. As we will show, under some assumptions, this will harm the environment.

A recent study illustrating this effect is Sarr and Swanson (2017). They focus on the rebound effect of transferring mitigation capital and build upon the model in Stokey (1998). In their model, a poor country gains utility ($U$) from consumption ($c$) and natural capital ($N$). Production follows from the use of physical capital ($k$) and is used for consumption, physical capital investments and environmental management ($m$). Natural capital is a state variable, which falls with production but can increase with environmental management. This stock (e.g., rainforests, the climate or good local air quality) generates basic health and environmental services. Initially, a poor country has a high level of natural capital ($N_0$) and a low level of physical capital ($k_0$). Development occurs through capital conversion from $N$ to $k$.

The poor country aims to maximize its net present value of utility:

$$(11) \qquad W\left(k(0),\mathrm{N}(0)\right)=\max_{c(t),m(t)}\int_0^\infty U\left(c(t),N(t)\right)e^{-\rho t}dt\,,$$

where:

(12) $\dot{k}(t) = f\left(k(t)\right) - c(t) - m(t)$,

(13) $\dot{N} = \Psi\left(m(t)\right) - \phi f\left(k(t)\right)$.

The function $\Psi(\cdot)$ describes the effectiveness of environmental management, and $\phi$ is a parameter describing resource intensity, or the deterioration of the natural resource following from production. In the model, a transfer of mitigation technology means a lower value of this parameter. The authors assume that $0 < \phi \leq \Psi'(0)$, meaning that the marginal productivity of environmental management is initially greater than emissions per unit of production.

Solving the optimization problem indicates that there will be no environmental management ($m = 0$) until time $\tilde{t}$. This is determined by the shadow price of physical capital being equal to the shadow price of natural capital. Before $\tilde{t}$, the shadow price of physical capital is higher, and therefore it is beneficial to increase physical capital at the expense of lower natural capital. However, for $t > \tilde{t}$, environmental management is provided to ensure the optimal balance between the two capital stocks.

A transfer of technology means that the resource intensity falls, i.e., there is less pollution or resource degradation per unit of production. For instance, this can result from new renewable energy that replaces fossil fuels or an end-of-pipe installation that reduces emissions. However, the result is that $\tilde{t}$ increases, and the social planner delays the commencement of environmental management. Lower resource intensity means that the natural resource becomes less scarce and, therefore, the shadow price is lower, so that the degradation of the natural resource continues for a longer time before the two shadow prices become equal.

This does not necessarily mean that the natural resource will be more depleted in the end, as the technology results in lower emissions per unit of production at all times after it has been implemented. The technology transfer increases the steady-state level of physical capital because it is less damaging. Thus, the transfer actually operates as a wealth transfer, as more production is socially profitable. This has two effects. Greater wealth increases the demand for normal goods. Given the preference structure, demand for both consumption and natural resources will increase. However, more consumption may be damaging for the natural resource. Whether the stock increases or decreases depends on the efficiency of $m$, $\Psi(m)$, and preferences for consumption. If the effectiveness of environmental management is low, the poor country may end up with a lower natural resource stock as a result of the mitigation transfer. Thus, there may be a rebound effect that outweighs the mitigation technology transfer.

Another recent paper focusing on a possible negative environmental effect of mitigation technology transfer is by Glachant et al. (2016). They show that trade in polluting goods can lead to transfers having a negative environmental impact, by introducing a static partial equilibrium North–South model, in which both regions produce a homogenous polluting good sold in the global market. Each region has one firm and there is imperfect competition in the international polluting good market. Production of the polluting good is costless, but it creates GHG emissions that have a negative impact on welfare in both regions. Thus, there are two market imperfections: imperfect competition and environmental externalities. However, environmental technology can reduce emissions, and the technology is initially better in the North than in the South, meaning that the North can produce the same amount of the polluting good with lower emissions. A technology transfer makes this technology available for the South at no cost, and it is assumed that adoption is costless.

The two regions, $i = N, S$, aim to maximize their welfare, which is the sum of consumer surplus ($CS_i$) and profit ($\pi_i$) less environmental damage. Environmental damage is the sum of the emissions from the two regions, which is translated into damage by the coefficient $\delta_i$. Thus, damage from climate change may differ between the regions. To deal with climate change, the regions set caps on their emissions. These are set noncooperatively, i.e., each region sets its own emissions cap, given the decision of the other region. Denoting a region's initial decision on emissions caps as $E_i$, and assuming no permit trading between regions, we have:

$$(14) \qquad \max_{E_i} W_i\left(E_i, E_j\right) = \pi_i + CS_i - \delta_i\left(E_i + E_j\right).$$

Caps reduce profits and consumer surplus (via increased production prices) but yield an environmental benefit. The optimal cap balances this. The cap is set strategically, as a higher cap in one region means that the other region can reduce its cap.[13]

First, the regions set caps noncooperatively without transfers, but they then revise them after transfers, as transfers reduce carbon prices in both regions. This is the result of the lower marginal cost of emissions reductions in the South, but the price also falls in the North because of a partial reallocation of production to the South. However, the technology transfer has an ambiguous effect on the environment. First, global production increases because production in the South is now more effective, as there is less environmental damage. Pollution falls in the North, as production decreases following its partial reallocation to the South. Therefore, emissions in the North (and the cap) go down. However, as a result, production in the South increases, and the effect on pollution (and the cap in the South) is ambiguous. Thus, a transfer of technology will not necessarily reduce emissions.[14]

### *4.2 Adaptation Transfers*

Now, we turn to the other type of transfer, namely adaptation transfers, which are part of the climate finance provisions under the UNFCCC. Adaptation means taking action to prepare for unavoidable climate change, such as building dikes, relocating buildings and infrastructure, changing agricultural crops and so on. The economic literature focuses on the nonexcludable benefits from mitigation, given that the atmosphere is a public good. However, there are often excludable benefits of adaptation. Adaptation is primarily a private good, the benefits of which accrue only to the nation undertaking the adaptation investment (Kane and Shogren 2000; Barrett 2008). Therefore, in the absence of barriers (such as international capital market constraints), nations should have incentives to undertake appropriate investments in adaptation, in contrast to the case of mitigation.[15]

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[13] Note that there are two externalities and that the carbon price in a region corrects the underprovision of the good arising from imperfect competition, in addition to correcting the environmental externality.

[14] The effects of a transfer for the North are as follows. There is a negative impact on profit from lower production; a lower production price (due to higher production globally) increases consumer surplus; and there is an ambiguous effect on the environment. Because of the functional forms used in the model, the North will not transfer technology if the transfer increases emissions. The positive impact of the transfer on consumers never compensates for the negative impacts on profits and the environment. However, if there is trade in emissions permits, a technology transfer reduces the permit price. Thus, if the North is a net buyer of permits, it has an additional incentive to transfer technology. On the other hand, the South will always accept the transfer.

[15] This assumes that the government takes into account the welfare of the nation.

However, there are certain mechanisms that “relax” the private good nature of adaptation actions by creating externalities (Buob and Stephan 2013). First, adaptation may affect international trade through economic growth and terms of trade changes (e.g., changes in food prices in response to investment in different crops). In addition, adaptation may have impacts on other countries through international security issues and conflicts. An example is measures to address a lack of drinking water, as measures taken to meet future demand for drinking water may reduce possible future conflicts over the use of scarce reservoirs. Another mechanism that may create externalities is climate migration, as we will discuss further in Section 4.4. Adaptation may improve living standards for people and, therefore, reduce their incentive to migrate. As noted above, transfers may help increase the stability of climate coalitions, and adaptation transfers can also work in this manner.

A final mechanism that we focus on arises from the possible interactions between adaptation and mitigation; examples of studies on this mechanism include Kane and Shogren (2000), Ingham et al. (2007, 2013), Tulkens and van Steenberghe (2009), Buob and Stephan (2011, 2013), Ebert and Welsch (2012) and Bréchet et al. (2013). Buob and Stephan (2013) provide a good illustration of these interactions. In their static North–South model, adaptation is a private good, but it may interact with mitigation. They assume that the North (*N*) has a mitigation target, but not the South (*S*). However, the South may reduce or increase emissions in response to the target set by the North. Both regions can adapt to climatic changes, and the North can fund adaptation in the South.

The available income of a region, called green GDP, is a function of an exogenously given conventional income (*y*), global mitigation (*M*) - as the environment is a public good, where $M = m_N + m_S$, and $m_n$ is the mitigation in region *n*, where $n = S, N$ - and, finally, adaptation (*a*). The green GDP, $F_n(y_n, M, a_n)$, is increasing and concave in all variables. The costs of mitigation, $g_n(m_n)$, and adaptation, $h_n(a_n^n)$, are strictly convex, and there is also a strictly convex cost of transferring adaptation to the other region, i.e., $h_n(a_n^i),\ \mathrm{i} \neq \mathrm{n}$. However, by assumption, the South will not transfer adaptation to the North, so the transfers only go to the South.

Each region aims to maximize regional welfare, which is a function of consumption, i.e., $U_n(\mathrm{c}_n)$. The budget condition is:

(15) $$F_n\left(y_n, M, a_n\right) - g_n\left(m_n\right) - h_n\left(a_n^n\right) - h_i\left(a_i^n\right) \geq c_n, \quad \mathrm{i} \neq \mathrm{n}.$$

The mitigation, adaptation and transfer decisions are studied in a Stackelberg game, where the North is the leader and the South is the follower. The stages of the game are as follows:

- Stage 0: The North commits itself to $\bar{m}_N$, which is common knowledge.
- Stage 1: The North simultaneously decides on $a_N^N$ and $a_S^N$. These choices then become public.
- Stage 2: The South simultaneously decides on $m_S$ and $a_S^S$.

The North calculates how its decisions will change the behavior of the South before deciding on its climate policies. From the South's optimization problem, the North finds that:

(16) $$\frac{dm_S}{d\bar{m}_N} \in \left(-1, 0\right),$$

(17) $$\frac{da_S^S}{d\bar{m}_N} \begin{cases} > 0 & if \ F_S^{a_S, M} > 0 \\ = 0 & if \ F_S^{a_S, M} = 0 \\ < 0 & if \ F_S^{a_S, M} < 0 \end{cases}.$$

The first result is that a tighter mitigation target in the North will reduce mitigation in the South. Thus, there is carbon leakage, but this will not outweigh the additional mitigation in the North, and the environmental impact will be positive (*M* will increase).

The impact of mitigation in the North on adaptation in the South will depend on the interaction between mitigation and adaptation. As *M* increases, adaptation will increase if there is strict complementarity, and fall if mitigation and adaptation are substitutes. In the latter case, the higher green GDP that follows from more global mitigation is used for consumption only.

An adaptation transfer to the South will affect the decisions in the South in the following way:

$$(18) \qquad \frac{da_S^S}{da_N^S} \in \left(-1, 0\right),$$

$$(19) \qquad \frac{dm_S}{da_S^N} \begin{cases} > 0 & if \ F_S^{a_S,M} > 0 \\ = 0 & if \ F_S^{a_S,M} = 0 \\ < 0 & if \ F_S^{a_S,M} < 0 \end{cases} .$$

There will be some crowding out of the South's own adaptation investments, but the total amount of adaptation will increase. Whether an adaptation transfer leads to more or less mitigation in the South will again depend on whether mitigation and adaptation are substitutes or complements. In the case where they are substitutes, the South decides to reduce its mitigation efforts, and, instead, the transfer will lead to higher consumption in the South.

Not surprisingly, it is not in the North's interest to transfer adaptation capital to the South if mitigation and adaptation are substitutes. In this case, the North will incur expenditure on adaptation transfers and suffer from less global mitigation. Only in the case where adaptation and mitigation are complements for the South will it be in the interests of the North to provide adaptation transfers; the South will increase its mitigation, which will benefit the North.

What do we know about the interactions between adaptation and mitigation? Planting trees for coastal protection or to reduce desertification are examples of actions where adaptation and mitigation are complements. On the other hand, both adaptation and mitigation compete for the same scarce resources, and both can reduce the impacts of climate change, which implies that they may be substitutes. The literature seems to be split on this issue; for instance, whereas Yohe and Strzepek (2007) argue for complementarity, Tol (2005) and Ingham et al. (2013) support the substitution assumption.

Can adaptation transfers still play a role? Fairness considerations may matter. Grasso (2010) argues for adaptation transfers from the perspective of international justice. As long as climate change is a matter of international justice, adaptation funds should be raised based on the responsibility for climate impacts, and the most vulnerable should have priority in receiving the funds. Pittel and Rübbelke (2013a) also argue that adaptation support may be a way to correct unfairness due to past contributions to global warming, and it may prevent damages from historical emissions. A similar conclusion is found in Rübbelke (2013), who argues that adaptation transfers may increase the prospects of success in international negotiations on climate change, as they bring the fairness issue to the table.

Adaptation support may play a similar role to pure monetary transfers. If it crowds out adaptation in the South, it will increase resources available for consumption and conventional capital accumulation. This may be good from a purely distributional perspective, but if the North distrusts the institutions in the South, it may not necessarily believe that the transfer will result in a better distributional outcome or a better production capacity in the region, considering it, instead, to be a waste of resources (Pittel and Rübbelke 2013a).

Given the possibility of crowding out, could the North still influence adaptation in the South? One answer to this involves the concept of conditional support, which may also assist in overcoming distrust that resources will “disappear”. Support can be conditional on, for instance, increasing adaptation or mitigation investments in the South. Pittel and Rübbelke (2013b) show that both regions can gain in the case of conditional adaptation transfers, but that the outcome depends on the productivity of the different technologies. Below, we will further examine both fairness considerations and conditional transfers, and also how the different instruments of climate finance interact with another transfer from the North to the South, namely development aid.

### *4.3 Climate Policy and Development Aid*

Even without climate finance, there are considerable transfers from the North to the South in the form of development aid. In 1970, the UN General Assembly suggested that rich countries transfer 0.7% of their gross national income to official development assistance. Although this aim has not been met by many rich countries, it remains on the agenda.

Development aid is seen as an important mechanism to reduce poverty and increase economic growth in the low-income world, even taking into account the debates on its effectiveness (e.g., Dollar and Easterly 1999; Collier and Dollar 2002, 2004; Bourguignon and Sundberg 2007). In addition, it is argued that development will reduce vulnerability to climate change (Schelling 1992) and that development aid is an instrument to achieve this (Tol 2005). However, Bowen et al. (2012) claim that not all growth reduces vulnerability, which has implications for growth policies. According to their study, policies that do reduce vulnerability include investment in skills and access to finance.

Based on this discussion, development aid can be a substitute for adaptation policies. On the other hand, development requires the use of more energy, which can increase GHG emissions. This means that development aid interacts with both adaptation and mitigation, and therefore one would expect development aid to have implications for mitigation and adaptation transfers.

### *4.3.1 Interactions Between Development Aid and Climate Finance*

These interactions between development aid and mitigation and adaptation transfers are studied in Eyckmans et al. (2016). They present a two-period North–South model, in which there is a global international agreement (e.g., the Paris Agreement) that sets region-specific upper limits for total GHG emissions over specified time periods. Both regions mitigate to meet the climate agreement, but they can also take adaptive measures, with adaptation and mitigation being substitutes, as discussed above. The North can transfer mitigation and adaptation technologies, in addition to development aid, to the South. These transfers are not primarily made for strategic reasons because the North cares about the South, as represented by the inequality aversion expressed in consumption. Therefore, some relevant questions are how the interactions studied above work under such an agreement, and how development aid interacts with adaptation and mitigation. For climate finance, it would be interesting to determine whether there is room for adaptation transfers that are not conditional.

Important aspects of the model are shown in the table below.

| | Period 0 (now) | Period 1 (future) |
|---|---|---|
| *N* (North) | $c_N^0 = y_N^0 - m_N - a_N - T^m - T^a - T^i$ | $c_N^1 = \left[1 - \left[1 - \alpha_N\left(a_N\right)\right] D_N\left(\hat{e}\right)\right] y_N^1$ |
| | $e_N^0 = \sigma_N\left(m_N\right) y_N^0$ | $e_N^1 = \sigma_N\left(m_N\right) y_N^1$ |
| *S* (South) | $c_S^0 = y_S^0 - m_S - a_S$ | $c_S^1 = \left[1 - \left[1 - \alpha_S\left(a_S + T^a\right)\right] D_S\left(\hat{e}\right)\right]\left[y_S^1 + T^i\right]$ |
| | $e_S^0 = \sigma_S\left(m_S + T^m\right) y_S^0$ | $e_S^1 = \sigma_S\left(m_S + T^m\right)\left[y_S^1 + T^i\right]$ |

**Table 1:** Consumption and emissions levels in each region and period.

Each region produces an exogenous output, *y*, which results in GHG emissions, *e*. The regions can invest in mitigation, *m*, that reduces emissions per output, i.e., $e_j^t = \sigma_j(m_j)y_j^t,\ j = N, S, t = 0{,}1$, where $\sigma$ is an emissions coefficient falling in *m*.

Even with a climate agreement, aggregated emissions over both periods ($\hat{e}$) result in climate damage that reduces available output in the second period by a fraction $\left(1-\alpha\right)D(\hat{e})$. To counteract this, the regions can invest in adaptation, *a*, which reduces damage in the second period, $0 \le \alpha_j\left(a_j\right) \le 1$, with $\alpha_j' \ge 0$.

In the first period, the North can transfer mitigation technology ($T^m$), adaptation technology ($T^a$) and development aid ($T^i$) to the South. Mitigation transfers reduce emissions in the South in both periods, whereas adaptation transfers reduce damage in the second period, and development aid increases the output of the South in the second period. The two regions consume ($c_j^t$) what is left of income after mitigation and adaptation expenditures and transfers (in the North only) are deducted. In the second period, no transfers are made, and all income left after damage from climate change is consumed.

Both regions gain utility from consumption. The intertemporal utility function in the South is $U_S\left(c_S^0, c_S^1\right) = c_S^0 + \delta_S c_S^1$, whereas the North also cares about consumption in the South, and it has inequality aversion in consumption, based on Fehr and Schmidt (1999). Here $\mu$ is a parameter expressing the intragenerational preferences of the North, whereas $\delta_j$ is the region-specific discount rate, expressing the intergenerational preferences:

$$(20) \qquad U_N\left(c_N, c_S\right) = c_N - \mu(c_N - c_S) = (1-\mu)c_N + \mu c_S, \quad c_j = c_j^0 + \delta_j c_j^1,\ j = N, S\ .$$

The optimal allocations of transfers, mitigation and adaptation are found by maximizing the respective regions' utility functions given the restrictions. This is modelled as a leader/follower game, where the North takes into account the South's reactions.

The results show that an agreement creates problems for mitigation transfers. There is typically a crowding out of mitigation efforts as the emissions target determines mitigation in the South. Conditional transfers in the form of matching grants[16] may increase mitigation, to a level in excess of the target, as there is incomplete crowding out of mitigation efforts, but the welfare effects for the South will be lower compared with the case of unconditional transfers.

Development aid increases mitigation, as higher output results in more emissions, and the South has to meet its emissions target. However, a climate target makes development aid less efficient because part of the transfer is used for mitigation.[17] Not surprisingly, adaptation technology transfers will completely crowd out adaptation investments in the South, unless a matching grant support function is used. However, an increase in development assistance will increase the adaptation level of the South. The reason is that more value is at risk, which gives an incentive to increase adaptation.

So far, the conclusions for adaptation transfers are not very promising, as the South has all the incentives to undertake the optimal adaptation actions itself without transfers. However, this conclusion may change if the South is very poor. This is specified as a constraint on consumption, such that consumption should be at least equal to some minimal subsistence level. If this constraint is binding, the South struggles to feed its population. In this case, the conclusions for mitigation are not changed if the South decides to meet its emissions targets. However, this yields some new results for adaptation, as the optimal adaptation investments are not necessarily made. Mitigation support results in more adaptation, as there is complete crowding out of mitigation, which frees resources for adaptation. Adaptation support and transferring consumption goods also work in the same way. However, development aid results in lower adaptation investments in the South. The reason is that development aid results in higher emissions in the second period, which require more mitigation investments at the expense of adaptation investments in the first period. To conclude, if the aim is to increase adaptation in the South, adaptation transfers should be earmarked for very poor countries.

### *4.3.2 The Effects on Economic Growth*

In Eyckmans et al. (2016), climate policies have no effects on economic growth, whereas development aid has growth effects. In their model, climate policies only assist in reducing

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[16] For each dollar the South spends on mitigation, the North will spend an additional given amount on mitigation in the South.

[17] The authors argue that this opens the possibility for low-carbon development assistance, under which one can preserve the full effect of development transfers using a combined package of transfers for development and mitigation.

the damage from climate change, either through reduced emissions or reduced impacts. However, others have argued that climate policies may also have an effect on economic growth; Bovenberg and Smulders (1995) and Fankhauser and Tol (2005) provide early contributions. More recently, Bretschger and Suphaphiphat (2014) compare the growth effects of mitigation and development aid in a two-region endogenous growth model. The only transfer from the North to the South is development aid, but mitigation in the North also has an effect on economic growth in the South through spillover effects.

In Bretschger and Suphaphiphat (2014), capital is the only input factor in the economy, but there are two types of capital, conventional (*K*) and knowledge (*B*). Initially, the South (*S*) has a lower level of conventional capital than the North (*N*). Knowledge capital is accumulated only in the North, but it spills over to the South. Production results in GHG emissions and climate change, which harms both capital stocks through higher capital depreciation. Thus, the growth effect of climate change occurs via capital accumulation.

The production process in the North is a Cobb–Douglas production function with constant returns to aggregate capital, and *A* is total factor productivity:

$$(21) \qquad Y_N(t) = A_N B_N(t)^{\alpha} K_N(t)^{1-\alpha} .$$

Production in both regions, $Y_i$, results in GHG emissions, and therefore the stock of GHGs in the atmosphere, *P*, increases with production. Damage follows from changes in this stock and is region-specific due to the parameter $\mu_i$. What is left after consumption (*C*) and climate damage is invested in capital, with net investments differing from gross investments owing to capital depreciation. The natural depreciation rate is equal for both capital stocks ($\delta$). This means that climate damage has a direct effect on investments, but not on consumption, and therefore it works as an additional depreciation:

$$(22) \qquad \dot{K}_N(t) + \dot{B}_N(t) = Y_N(t) - C_N(t) - \delta\left[K_N(t) + B_N(t)\right] - \mu_N \dot{P}(t) .$$

For the South (*S*), the production structure is similar, except that knowledge is not invested in. However, a certain part, $0 < \theta < 1$, of knowledge capital in the North spills over to the South, i.e., $B_S(t) = \theta B_N(t)$. This therefore enters the production function, as shown in (21). Further, as the South does not invest in knowledge capital, damage from climate change in the South only affects its investments in conventional capital:

$$(23) \qquad \dot{K}_S(t) = Y_S(t) - C_S(t) - \delta K_S(t) - \mu_S \dot{P}(t)\,.$$

Finally, the aim of both the North and the South is to maximize the present value of the stream of utility over an infinite time horizon, where utility follows from consumption.

The results show that, on the balanced growth path, the consumption growth rates are equal in both regions for $A_N = A_S = A$. However, there is a constant gap in consumption and capital levels, as the South only accumulates physical capital and there are imperfect spillovers of knowledge capital. When it comes to climate impacts, there is a higher adverse effect of pollution in the South, as it also suffers from the negative effect of pollution in the North, even if we assume equal damage ( $\mu_N = \mu_S = \mu$, which is assumed below).

Now, consider a (permanent) mitigation policy in the North financed by a tax on consumption. The mitigation reduces the pollution by a fraction *m*:

$$(24) \qquad \dot{M}(t) = (1-m)\dot{P}(t)\,.$$

Then, the capital accumulation in the North with mitigation is:[18]

$$(25) \qquad \dot{K}_{mN}(t) + \dot{B}_{mN}(t) = Y_{mN}(t) - (1+\tau)C_{mN}(t) - \delta\left[K_{mN}(t) + B_{mN}(t)\right] - \mu\dot{M}(t)\,.$$

Due to the tax, the consumption level in the North falls instantaneously. However, long-run consumption will be higher, as the growth rate increases because capital depreciation falls.

The mitigation policy in the North creates a positive externality for the South, as the negative impacts of climate change are lower. As a result, the consumption level in the South increases

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[18] Subscript *m* denotes the value of the variable under the mitigation policy, whereas subscript *d* means the value in the presence of development aid.

instantaneously. It also has a positive effect on long-term growth, as the knowledge capital that spills over from the North increases.

In contrast, (permanent) development aid from the North to the South financed by the same consumption tax will reduce consumption in the North but will not affect economic growth. The South receives the tax revenues as a lump sum transfer, and the new resource constraint of the South becomes:

$$(26) \qquad \dot{K}_{dS}(t) = Y_{dS}(t) + \tau C_{dN}(t) - C_{dS}(t) - \delta K_{dS}(t) - \mu \dot{P}(t) .$$

This transfer will not affect the growth equations as the growth on the balanced growth path follows the North. Thus, there is full crowding out of capital accumulation, and the consumption level of the South increases permanently. With a permanent increase in this consumption level, the gap in consumption between the two regions shrinks permanently. However, Bretschger and Suphaphiphat (2014) note that there are other ways of giving aid that may have growth effects. If aid is given in a way that reduces the delay in the diffusion of knowledge capital, or if a pure mitigation technology transfer is provided if the South spends at least part of the transfer on mitigation (a conditional transfer), then growth effects will occur.

When comparing the two policies, the North will always be better off as a result of the mitigation policy because its decrease in consumption is lower, owing to reduced damage from climate change, and the growth rate is higher. For the South, the growth rate will also be higher, but we cannot determine which policy results in the highest increase in consumption. In the long run, consumption will be highest with the mitigation policy, but what policy is considered the best from the South’s point of view depends on the evaluation period and the time preference rate.

The conclusions from Bretschger and Suphaphiphat (2014) are very different from those of Eyckmans et al. (2016). In Bretschger and Suphaphiphat (2014), development aid will not have any growth effects for the South, whereas mitigation policy in the North will. In Eyckmans et al. (2016), the conclusion is the opposite. Development aid will have a growth effect, whereas mitigation only affects consumption. These papers show that the conclusions are very dependent on the assumptions. In Eyckmans et al. (2016), development aid is earmarked for growth, whereas it is given as a lump sum transfer in Bretschger and Suphaphiphat (2014). Eyckmans et al. (2016) do not explicitly include capital accumulation but assume that the growth is independent of climate change. In contrast, Bretschger and Suphaphiphat (2014) assume that climate change damage harms the existing capital stock and does not have a direct effect on consumption.

### *4.4 Climate Migration*

Now, we turn to a transfer that is expected to proceed not from the North to the South, but rather in the opposite direction, namely a transfer of people through climate change-induced migration. The hypothesis that climate change induces migration and displacement[19] finds support both in historical data (Zhang et al. 2007) and in more recent periods. The prolonged drought that created "the Great Dust Bowl" in the US in the 1930s led to a large migration of people across the country (Rosenzweig and Hillel 1993). Droughts in Burkina Faso and Sudan forced one million people to move over a five-year period between 1968 and 1973 (Afolayan and Adelekan 1999), and several million people migrated from Bangladesh to India because of environmental changes (Swain 1996). In addition, a growing number of empirical studies link migration to climatic changes at both the national and international level (Mulligan et al. 2014; Marchiori et al. 2017). Predictions for climate change-induced migration in 2050 are obviously uncertain, and estimates range from many thousands up to several hundred million people being affected (Marchiori and Schumacher 2011; Gemenne 2011; Oppenheimer 2013).

Climate change is expected to affect migration mainly because it lessens economic productivity and reduces economic growth in various countries (Park and Heal 2013; Burke et al. 2015). Many developing countries have a warm climate, and the agriculture sector is particularly vulnerable to global warming and droughts, leading to (internal) migration from rural to urban areas. Indeed, agriculture-dependent countries may experience more migration problems (Cai et al. 2016).

According to Marchiori et al. (2012), migration arises from two channels: the economic geography channel and the amenity channel. The economic geography channel stresses that

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[19] It is common to distinguish between migration as a long-term consequence of gradual changes in environmental factors and displacement that occurs because of abrupt events, such as droughts and floods. Thus, migration may be the result of a succession of displacements.

weather anomalies reduce productivity in agriculture, which reduces wages and gives rural workers incentives to move to urban areas. In turn, this lowers urban wages, which increases incentives for international migration. Conversely, the amenity channel emphasizes the nonmarket costs of climatic changes, e.g., the spread of diseases and higher mortality, as push factors for migration. Marchiori et al. (2012) find proof of both mechanisms at work in sub-Saharan Africa.

Marchiori and Schumacher (2011) provide another mechanism for climate migration in a two-country overlapping-generations model. They assume that differences in welfare provide incentives for migration, and that the South (mainly) is hurt by climate change, which increases the North–South differences and the incentive for migration. The North may lose from migration owing to decreasing returns in production, whereas the South will gain. Migration from South to North will increase global emissions, as it is assumed that emissions from the South are negligible. Again, this reduces production and welfare in the South and reinforces the incentive to migrate.

Migration can be positive or negative for both receiving and sending regions. One positive effect for a receiving country with an ageing population may be an inflow of young labor. Thus, migration can balance the age structure and increase the country’s wealth. For the sending country, migration may be positive if the country is suffering from overpopulation and pressure on resources. On the cost side, migration between regions will affect the distribution of wealth and income within a region as well as across regions. For instance, a large wave of migrants from poor to rich countries can reduce the average income in the country, as migrants or refugees from poor countries typically belong to the lower part of the income distribution in a rich country. Thus, the income distribution in the country in which the migrants relocate may become more uneven. Prieur and Schumacher (2016) focus on conflicts following from climate migration, distinguishing between internal and external conflicts. For a receiving country, accepting immigrants may give rise to internal conflicts, as the population may be unwilling. On the other hand, not accepting the immigrants may cause external (international) conflicts.

Potential climate migration from poor to rich countries may change the incentives of policy makers. As mentioned in Section 4.2, it may create an incentive for adaptation transfers, as adaptation in the poor countries affects the migration stream and thus the rich countries. In addition, it may change the mitigation policy in the rich countries, as it contributes an additional climate change externality and therefore influences the incentives for mitigation. This is studied in a dynamic North–South model by Mason (2017), who shows that if migration imposes a cost on the North, then it imposes a pseudo carbon tax to lower emissions.

Mason (2017) uses the following assumptions. Production, $Q$, occurs only in the North, whereas the South trades the product so that marginal utility equalizes. $Q_1$ is consumed in the North, whereas $Q–Q_1$ is consumed in the South. The common value of the marginal utility is equal to the price of the commodity at the total level of production, i.e., $p(Q)$. The cost of production, $c(Q)$, is convex, and so is the damage from global warming, $d(Z)$. Damage increases with the stock of GHG ($Z$), which again increases with production, and it is higher in the South than the North (by a factor $\beta > 1$). The difference in damage, $(\beta - 1)d(Z)$, gives an incentive to migrate. However, there is a cost to migrate, $v$, which varies across individuals according to a probability distribution function, $\phi(v)$. Thus, the cutoff cost for migration, $\hat{v}$, is $\hat{v} = (\beta - 1)d(Z)$. According to this, the population in the North at each point of time, $\alpha$, will be the sum of its initial citizens, $\alpha_0$, and the immigrants. However, immigration causes "crowding externalities" in the North, $\eta\alpha$. These costs are related not only to immigrants but also to the total number of people living in the country.

The North maximizes the present value of the net benefits to its citizens, which equals the sum of consumer and producer surplus net of climate damages and crowding externalities, taking into account the dynamics of the stocks of GHGs and population. Note that in this maximization problem, the region only cares about the net benefits of its own citizens ($\alpha_0$).

$$(27) \qquad \max_{Q} \int_0^{\infty} e^{-rt} \left\{ \left[ u_1\left(Q_1\right) - d\left(Z\right) \right] \alpha_0 + p\left(Q\right) Q - c\left(Q\right) - \eta\alpha \right\} dt .$$

The main conclusion is that the shadow price of carbon is dependent on the shadow price of immigration. This results in a pseudo carbon tax on production that is higher than is the case without migration. Thus, the optimal response of the rich countries to climate migration is to increase mitigation. This means that potential migration results in a lower long-run carbon stock and a lower emissions path than would be the case without this threat. However, if migration were beneficial to the North ($\eta < 0$), the results would be reversed and emissions would increase.

## 5 Concluding Remarks

In this paper, we have studied the role of equity preferences and distribution in climate policies by presenting mechanisms and results from dynamic North–South models. If agents express preferences about the distributive outcome of policies, they may adopt climate policies that influence the distribution in the preferred direction. However, a more equal distribution of outcomes may result even in the absence of such preferences if there exist strategic reasons for transfers from the rich to the poor countries. We have presented results regarding when such transfers work according to the policymakers' intentions, or fail to do so. Climate migration is a transfer that occurs in the opposite direction, i.e., from the poor to the rich countries, and it may also affect distributional outcomes. It is possible that it may increase the incentives of the rich countries to implement climate policies to mitigate adverse distributional consequences, even if the rich countries are mainly concerned about their own outcomes.

One interesting question is whether distributional consequences will be taken into account in the future, when the current climate policies need to be tightened to meet the aims of the Paris Agreement. Solidarity among countries has changed during recent years, as is evident in events such as Brexit and the election of Donald Trump as the US President. There are also signs of anti-globalization sentiments in election campaigns and outcomes in several European countries. It is hard to know what this will mean for climate policies. However, it is important to note that there seems to be a tendency for regions or states within large countries to deviate from federal policies. Examples are the climate policies adopted in California and regional permit trading systems, such as the Regional Greenhouse Gas Initiative (RGGI) adopted on the east coast of the US, and the Western Climate Initiative (WCI), which includes emission trading between California and Quebec. Therefore, countries may not be the only important actors in climate policies in the future, but it remains to be seen how such alternative actors will take into account their effects on poor countries.

There have been a growing number of studies on equity preferences and the distributional consequences of climate policies over the past few years, but many unanswered questions remain in this field. In addition to studying whether equity issues really have an impact on the policies adopted, another question is whether the equity preferences that have been introduced in the dynamic models of climate policies are the most relevant. When it comes to transfers, more studies are required to explore growth effects and to avoid unintended consequences. This is especially important for adaptation transfers, which are essential for climate finance under the UNFCCC. However, the most important issue to study when it comes to transfers is climate-induced migration from poor to rich countries. This is a new topic in the economics of climate change, and how it will interact with climate policies or link climate policies to other policy areas is uncharted territory for economists.

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