Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

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August 2013

Centre for Climate Change Economics and Policy

Working Paper No. 143

Grantham Research Institute on Climate Change and the Environment

Working Paper No. 123

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Equity, Development Aid and Climate Finance

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5 July 2013

Abstract

This paper discusses the ethical underpinnings of climate finance. We ask what the optimal flow of financial assistance for mitigation (to reduce emissions), adaptation (to become climate resilient) and development (to increase income) would be if rich countries care about the inter- and intragenerational distribution of consumption in the world. The question is framed as a two-period game of transfers between two regions, North and South. We show that the level of financial assistance from the North will depend on the North's concern about well-being in the South, which we model as a Fehr-Schmidt utility function. Our main conclusion is that in the absence of market failures (e.g., barriers to adaptation or a weak carbon constraint) the most effective instrument to promote adaptation and mitigation in the South is a development transfer. In pure equity terms, development aid is a more effective instrument for achieving both intergenerational- and intragenerational equity.

Keywords: intergenerational equity; intragenerational equity; mitigation; adaptation; climate change finance; development assistance

JEL classification: D63, Q50, Q54, Q56

Acknowledgements: The project was supported financially by the MILJØ2015 program at the Research Council of Norway. Fankhauser also acknowledges financial support by the Grantham Foundation for the Protection of the Environment and the UK Economic and Social Research Council. We are also indebted to initial discussions with Scott Barrett and to comments from Katinka Holtsmark, Torben Mideksa, Linda Nøstbakken and seminar participants at the Frisch Centre. The authors are associated with CREE - the Oslo Centre for Research on Environmentally Friendly Energy - which is supported by the Research Council of Norway.

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1. Introduction

There is a strong ethical case for action against climate change. It is based on the observation that climate change could reverse recent development progress and push large population groups back into poverty. Climate change impacts fall disproportionately on the poor. The call for industrialized countries to take the lead in cutting emissions, even though they now account for no more than half of global greenhouse gas emissions, is also based on ethical arguments of justice and historical responsibility (see Stern, 2012, for an overview).

In the international negotiations, these ethical beliefs are expressed not only in the way the emission reduction burden is shared, but also in the level of financial transfers that are offered to low-income countries. In fact, climate finance has become a critical element of the search for a new global treaty on climate change. Under the Copenhagen Accord of 2009, and reaffirmed in subsequent negotiation documents, developed countries have promised to provide additional climate finance of up to $100 billion a year from 2020 to help developing countries to reduce their emissions and adapt to the consequences of climate change (Haites, 2011).

The offer for climate finance should be seen in a broader context of financial assistance to developing countries, as financial assistance has impacts on welfare, development, climate resilience and greenhouse gas emissions. Financial transfers to aid developing countries have a long tradition, starting with official development assistance, but also including help in dealing with other environmental problems, such as desertification or the loss of biodiversity. Indeed, climate finance is explicitly to be provided on top of conventional development assistance, which developed countries have pledged to increase to 0.7% of GDP as part of the Millennium Development Goals.

The twin commitments to both climate and development finance reflect the importance of climate change and poverty alleviation as two of the most important challenges of the 21st century. Today, more than 1.2 billion people are considered extremely poor, which means that they live on less than $1.25 a day.[1] Over the past

[1] See http://povertydata.worldbank.org/poverty/home/.

two decades the poverty head count has been reduced dramatically, particularly in Asia. Yet, the difference in GDP between the 20 richest and the 20 poorest countries in the world has doubled during the last 40 years, and many low-income countries are lagging far behind across a range of human development indicators (Collier, 2007).

At the same time, a failure to restrict climate change could undo much of the development progress of the past decades and threatens prosperity not just in the developing world (World Bank, 2010). Some warming is now unavoidable as the stock of greenhouse gases in the atmosphere builds up. The spectacular growth of emerging economies like India and China, which has done so much to lift people out of poverty, has also led to a dramatic increase in their greenhouse gas emissions and has shifted global emissions patterns. The balance of historical responsibility still remains with rich countries, but it is no longer possible (if it ever was) to curtail climate change without significant emission reductions by developing countries (UNEP, 2012).

This provides the backdrop against which developed countries have committed to provide funding for developing countries to alleviate poverty (development aid), reduce greenhouse gas emissions (mitigation finance) and prepare for unavoidable climate change (adaptation finance).

This paper explores the inter- and intragenerational equity issues that underpin the commitment to these financial transfers. The basic tenet is that the commitments reflect the ethical beliefs of those making them. That is, transfers are made not exclusively for strategic reasons, but primarily because people in developed countries care about the welfare of people in developing countries. We also assume that these beliefs can be expressed in an appropriately specified utility function, and study how the level and composition of financial flows depend on the ethical beliefs of developed countries (which, with apologies to the antipodes, we shall call the North).

Most of the existing literature on financial transfers focuses on their strategic value, that is, their merit in securing an international agreement (see e.g., Barrett, 2003, 2007 and Hong and Karp, 2012, on forming international environmental agreements). Already in the 1990s, Carraro and Siniscalco (1993) and Kverndokk (1994) argued that side payments mainly from OECD countries to non-OECD countries would be an effective policy instrument for making a limited treaty significant. Eyckmans and Tulkens (2003) show that a proportional surplus- sharing rule can stabilize a grand coalition and secure the first-best global climate policy, and Carraro et al. (2005) demonstrate the importance of monetary transfers as strategic instruments to foster stability of voluntary climate agreements. Further, Hoel (2001) argues that monetary transfers are also important to reduce carbon leakage, while Chatterjee et al. (2003) study transfers to promote economic growth and contrast the effects of a transfer tied to public infrastructure investments with a traditional pure transfer.

Our paper is part of a relatively new and growing literature on the interplay between adaptation and mitigation (see for instance Buob and Stephan 2011, Ebert and Welsch 2012; Tulkens and van Steenberghe 2009; Ingham et al. 2007; Bréchet et al. 2013). A recurring insight from this literature is the following. While the benefits of mitigation are non-excludable, the benefits of adaptation are often excludable, meaning that adaptation is primarily a private good and the benefits accrue only to the nation doing the adaptation investment (Kane and Shogren, 2000; Barrett, 2008).[2] Thus, nations should have the incentives to do the appropriate adaptation investment themselves in contrast to mitigation. Another issue in this literature is that adaptation and mitigation can be substitutes (Ingham et al., 2005). Thus, by reducing the effects of climate change, the incentive to mitigate may be lower and give a negative feedback to the donors. To overcome such difficulties, Pittel and Rübbelke (2013) develop a two-region model, similar to ours, to explore the merit of financial adaptation transfers that are conditional on mitigation efforts. Also Heuson et al. (2013) consider a stylized two-region model of mitigation and adaptation with different types of transfers from the industrialized region to compensate for mitigation and adaptation costs and expected and potential climate change damages in the developing region. In contrast to these approaches, we allow for development assistance (in the form of productive capital transfers) as an additional transfer channel and, more importantly, we consider a more general preference structure that allows for ethically motivated behavior.

[2] There are examples of adaptation actions with regional public goods features, such as the management of international water systems, but we can treat these as exceptions from the rule.

There is a considerable environmental economics literature[3] on climate change and both intergenerational and intragenerational equity, but it has little to say about climate finance (see Stern, 2012 for a recent synopsis). The intergenerational debate is dominated by the question of discounting, on which there is a vast body of research (e.g., Goulder and Williams, 2012; Stern, 2007; Heal, 2009; Dasgupta, 2008; Sterner and Persson, 2008; Nordhaus, 2007; Weitzman, 2007; Groom et al., 2005). Intragenerational equity issues have been reviewed by Kverndokk and Rose (2008). The main concern here has been the fair allocation of the emission reduction burden across countries, recognizing differences in factors such as income, abatement cost and historical responsibility (Stern 2012). There is also research on the incidence of carbon policies within a country, which often fall disproportionately on poor households (Bye et al., 2002; Abdallah et al., 2011). Not many papers study the linkages between intergenerational and intragenerational issues of climate change. One exemption is Kverndokk et al. (2012) who analyze the implications for climate treaties of inequality aversion within a generation. They find that this gives a higher burden of mitigation for the developed world, while the developing world may be allowed to increase their emissions as a result of development to reduce consumption inequality.

This paper departs from the existing literature in several respects. First, unlike the side payment literature we treat financial transfers as an equity issue rather than a strategic question. Transfers are determined by ethical preferences and not by the need to secure cooperation (although there are, inevitably, some strategic effects). Second, we have a narrower interest than the equity literature by focusing specifically on the ethics of financial transfers. Unlike much of that literature we are not concerned with optimizing global social welfare. Rather than a global perspective, we take the point of view of developed countries and ask what type of transfers their ethical preferences imply. The type of transfers we consider constitutes the third difference. While the literature focuses predominantly on mitigation finance (which reduces emissions), the main choice in our model is between development aid (which increases output) and adaptation finance (which reduces impacts of climate change).

[3] See for instance Grasso (2012), and references therein, for an overview of philosophical approaches to fairness in global cooperation on climate change mitigation and adaptation.

To be able to focus on equity issues we build a model that does not contain any market distortions that are not internalized. In particular, there are no barriers to either effective adaptation or effective economic management (such as poor institutions), and we assume a binding global emissions constraint to address the climate change externality. We find that under these assumptions the most effective instrument for climate finance is a development transfer. If the development transfer promotes growth, it will also increase adaptation and mitigation in the poor region, as well as raising the consumption level of that region. Development transfers are thus an effective instrument for achieving intergenerational- and intragenerational equity. The corollary is that, rather than being an instrument of equity, climate finance is justified primarily as a way to overcome prevailing barriers to both mitigation (i.e. the absence of a global emissions constraint) and adaptation (e.g., constraints to adaptive capacity).

The paper is structured as follows. Section 2 sets out our theoretical model. It features a two-period game of transfers from North to South with utility functions that include the welfare in the other region. In Section 3 we study the emission permit market and mitigation decisions of the regions when there is an international treaty regulating the total emissions over the two periods. Section 4 analyzes the adaptation choices of the South, while Section 5 concentrates on the optimal transfers from the North. The final section concludes.

2. A two-period game of transfers

Our model is structured as a simple game between two regions, j, over two periods (*t = 0,1*). The two regions are called *North* (*j* = N) and *South* (*j* = S), where North is a rich region and South is poor. Each region produces an exogenous output y_j^t, which results in greenhouse gas emissions e_j^t.[4] The combined emissions from both regions result in climate change damage, which reduces available output in period 1. Damage in period 0 is assumed to be negligible.

In period 0 each region chooses the amount it wishes to invest in mitigation technology m_j and adaptation technology a_j. The benefit of adaptation is reduced

[4] Thus, we implicitly assume that real capital investments are made optimally.

impacts from climate change in period 1. We assume that climate change damage in country j, D_j, is a constant share of output, and that a fraction, α_j, of this damage can be avoided through adaptation. Investing in adaptation has decreasing returns: $0 \le \alpha_j(a_j) \le 1$ with $\alpha_j' \ge 0$ and $\alpha_j'' \le 0$. These are simplifying assumptions but they are common in the literature (e.g., Fankhauser, 1994; Kverndokk, 1994; Tol, 2002; Nordhaus and Boyer, 2000; de Bruin, Dellink and Tol 2009; de Bruin, Dellink and Agrawala 2009).

The benefit of investing in mitigation is lower emissions for a given level of production. Mitigation capital is long-lived so that the choice of m_j determines emissions over both periods. Emissions are proportional to output, that is, $e_j^t = \sigma_j(m_j)y_j^t$, where $\sigma_j(m_j)$ can be interpreted as the emission-to-output ratio. We assume that mitigation investment has decreasing returns (equivalently, abatement costs functions are convex): $\sigma_j' < 0$ and $\sigma_j'' \ge 0$.

There is an international agreement to constrain total emissions over both periods and regions so that $e_N^0 + e_N^1 + e_S^0 + e_S^1 \le \hat{e}$.

The aggregate target $\hat{e}$ is the sum of individual targets by regions and time periods, $\hat{e} = \Sigma_j \Sigma_t \hat{e}_j^t$. The difference between the emissions target and actual emissions creates a financial flow, $p(\hat{e}_j^t - e_j^t)$, where p is the intertemporal market-clearing carbon price. The carbon market provides the incentive to invest in mitigation.[5] The existence of a global carbon market of this type, with free arbitrage across regions and time periods, is a strong assumption. However, the presence of emissions trading per se is not.

The North can make three types of transfer in period 0:

[5] An alternative formulation would be to associate the benefit of mitigation directly with reduced damage. However, this would introduce climate change as a strategic externality into the model and make it difficult to distinguish the equity case for transfers from the efficiency case. Moreover, our representation is not unrealistic. Very few countries are large enough to influence global emissions. For most, the incentive to reduce emissions comes from an exogenously agreed target and/or the prospect of carbon market revenues, rather than the possibility to reduce damage directly.

- a productive capital transfer (development assistance), T^i, which will increase the available output (and emissions) of the South in period 1,[6]
- a mitigation transfer, T^m , which helps the South reduce its emissions in both periods
- an adaptation transfer, T^a, which augments the adaptation capital available to the South.

The transfers introduce some intra- and intergenerational tradeoffs. Mitigation efforts (and mitigation support) have an immediate and lasting impact because it lowers the emission intensity in both periods. Adaptation and productive capital support however, are subject to a time delay. Today's investment only pays off in the next period. Hence, we assume that changing the productive capital base and adaptation capacity of a country requires more time than curbing its emission intensity.[7]

The output that is left after transfers and investments in mitigation and adaptation in period 0 is consumed. The consumption levels in each region and period, c_j^t, and the corresponding emissions, e_j^t, can now be specified, as follows:

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

[6] We could also have introduced a pure consumption transfer, but that would not make sense in this model due to the specification of the welfare function, see footnote 11 below.

[7] In reality, there will also be quick wins in improving adaptation capacity and productivity. At the same time, some mitigation efforts will only curb emission intensity in the long run. We abstract from these possibilities mainly because it allows us to keep the model tractable.

This describes the pay-off function and environmental consequences of a non-cooperative Nash game. The final, crucial element of the model is each region's utility function. We assume that both regions gain utility from consumption (that also includes feedback from the environment). For simplicity we assume linear utility functions, and we can write the intertemporal utility function of the South as

(1) $$U_S\left(c_S^0, c_S^1\right) = c_S^0 + \delta_S c_S^1$$

where δ_S is the consumption discount factor of the South, expressing the intergenerational equity preferences of the region.

To be able to study transfers from North to South that are not only motivated by strategic reasons, we assume that the North also cares about the intragenerational distribution of consumption, that is, consumption in the South. One way of doing this is to follow Fehr and Schmidt (1999) and assume that the North expresses inequality aversion in consumption;[8] the North dislikes that the South is poorer than them, but would dislike it even more if the South were richer.[9] Obviously, as North is the richer region initially, and would not make transfers that make the South richer than them, we have $c_N > c_S$. The utility function of the North can then be written as

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

[8] We could also introduce the inequality preferences in the welfare function of the South as in Kverndokk et al. (2012). This would give preferences for a higher consumption level in the South. However, as will be obvious from the discussions in Sections 3 and 5 below, equity preferences will not affect the optimal mitigation and adaptation levels, and inequality aversion in the South would not matter for our analysis.

[9] The general case would be $\mathrm{U_N}\left(\mathrm{c_N}, \mathrm{c_S}\right) = \mathrm{c_N} - \eta \max\left\{\mathrm{c_S} - \mathrm{c_N}, 0\right\} - \mu \max\left\{\mathrm{c_N} - \mathrm{c_S}, 0\right\}, \quad \mathrm{c_j} = \mathrm{c_j^0} + \delta_j \mathrm{c_j^1}, \;\; \mathrm{j = N, S}$, where η is a parameter representing the negative feeling of being worse off than the South, while μ is the parameter representing the negative feeling of being better off. We then have that $\eta \geq \mu$. The second part of the welfare function equals zero as $c_N > c_S$.

where $\mu > 0$ is a parameter expressing the intragenerational preferences of the North, while δ_N is the discount rate of the North, expressing its intergenerational preferences.[10]

From (2) we see that $\mu < 1$ for consumption in North to add to North's welfare. In addition, it is reasonable to assume that consumption in North adds more to the utility of North than consumption in South. Thus, we set $\mu < 1/2$.[11]

3. Emission permits market equilibrium and mitigation

The climate treaty gives an incentive for mitigation. To find the optimal mitigation levels, we first consider the optimization problem of the *South* with respect to mitigation. This is given by:

(3)

$$\begin{aligned}
\max_{m_S} \quad U_S &= c_S^0 + \delta_S c_S^0 = y_S^0 - m_S - a_S + p\left[\hat{e}_S^0 - e_S^0\right] + \\
&\delta_S\left\{\left[1 - \left[1 - \alpha_S(a_S + T^a)\right]D_S(\hat{e})\right]\left[y_S^0 + T^i\right] + p\left[\hat{e}_S^1 - e_S^1\right]\right\} \\
&= y_S^0 - m_S - a_S + p\left[\hat{e}_S^0 - \sigma_S\left(m_S + T^m\right)y_S^0\right] + \\
&\delta_S\left\{\left[1 - \left[1 - \alpha_S(a_S + T^a)\right]D_S(\hat{e})\right]\left[y_S^1 + T^i\right] + p\left[\hat{e}_S^1 - \sigma_S\left(m_S + T^m\right)\left[y_S^1 + T^i\right]\right]\right\}
\end{aligned}$$

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[10] With this specification, the North has preferences about the difference in (discounted) average consumption over the two periods, so we could have big differences between the two periods, but equal average consumption in the two regions. In that case equity preferences would not matter. However, we have assumed that North is the richest region in both periods.

[11] As mentioned in footnote 6, we could also introduce a consumption transfer from North to South in both periods as a means to reduce consumption inequality. However, as we have assumed that $\mu < 1/2$, no interior solution would be possible from the optimization problem, and there would not be any consumption transfer between the two regions. This is because utility is linear in consumption, and the North will always prefer one extra consumption unit to itself than to the South. Note, however, that with a concave utility function, we would get an interior solution, and the marginal utility of consumption as well as the equity weights will determine the outcome. If $\mu = 1$ so that North does not care about the welfare level of the South, there will not be any consumption transfer even in this case. The reason is that the consumption transfer has no strategic effect. The only reason to transfer consumption is that the North cares about the welfare of the South.

The necessary first-order condition (FOC) for an interior solution with respect to mitigation effort m_S is given by $-1-p\sigma'_S y_S^0-\delta_S p\sigma'_S\left[y_S^1+T^i\right]=0$,[12] which implies

$$(4)\qquad -1/\left(\sigma'_S(m_S+T^m)\left[y_S^0+\delta_S\left(y_S^1+T^i\right)\right]\right)=p\,.$$

Thus the discounted sum of the marginal mitigation cost (the left hand side of the equation) equals the price of permits (*p*). The FOC determines mitigation effort as an implicit function of the price of permits *p* and the support levels T^i and T^m. Note that adaptation is not present in the FOC of mitigation effort meaning that we can study the mitigation decision separately.

For the *North*, the optimization problem with respect to mitigation is:

(5)

$$\begin{aligned}\max_{m_N}\ U_N=&(1-\mu)\left(y_N^0-m_N-a_N-T^a-T^i-T^m+p(\hat{e}_N^0-\sigma_N(m_N)y_N^0)\right)\\&+\mu\left(y_S^0-m_S-a_S+p(\hat{e}_S^0-\sigma_S(m_S+T^m)y_S^0)\right)\\&+\delta_N\begin{bmatrix}(1-\mu)\left(y_N^1\left(1-(1-\alpha_N(a_N)\right)D_N(\hat{e}))+p(\hat{e}_N^1-\sigma_N(m_N)y_N^1)\right)\\+\mu\left((y_S^1+T^i)\left(1-(1-\alpha_S(a_S+T^a)\right)D_N(\hat{e}))+p(\hat{e}_S^1-\sigma_S(m_S+T^m)(y_S^1+T^i))\right)\end{bmatrix}\end{aligned}$$

An interior solution for the optimal mitigation effort is characterized by a similar FOC, but in this case it does not depend on the level of mitigation and productive capital support:

$$(6)\qquad -1/\left(\sigma'_N(m_N)\left[y_N^0+\delta_N y_N^1\right]\right)=p\,.$$

[12] This assumes that the countries take the price of permits as given and do not try to manipulate it. Thus, we consider a system of many price taking firms trading emission permits. In addition, sufficient conditions for an interior solution are that the first unit of investment in mitigation has a very large effect on the emission-to-output ratio ($\sigma'_i(0)=-\infty$) and that this effect vanishes for very large investments ($\lim_{m_i\to+\infty}\sigma'_i(m_i)=0$).

This implies that the mitigation function of the North only depends on the permit price *p*.

Totally differentiating the FOC for optimal mitigation effort of the South yields the following expression:

(7)

$$-dp\sigma_S'\left[y_S^0+\delta_S\left(y_S^1+T^i\right)\right]-p\sigma_S''\left[dm_S+dT^m\right]\left[y_S^0+\delta_S\left(y_S^1+T^i\right)\right]-p\sigma_S'\delta_S dT^i=0$$

It therefore follows that the impact of the price of permits on the mitigation effort of the South is

(8) $$\frac{dm_S}{dp}=\frac{-\sigma_S'}{p\sigma_S''}>0\,.$$

Hence, South's mitigation effort increases in the price of permits as expected.

A similar expression holds for the North:

(9) $$\frac{dm_N}{dp}=\frac{-\sigma_N'}{p\sigma_N''}>0\,.$$

However, the price of permits is not exogenously given; it is an endogenous variable in the model. It is more interesting to study how mitigation depends of the policy variables that are so far assumed exogenous; the transfers and the total emission level.

To do this, we need to work with the complete system of equations consisting of the FOC of North and South ((4)and(6)) and the permit market balance condition given by

(10) $e_N^0 + e_N^1 + e_S^0 + e_S^1 = \hat{e}$

To save on notation, we will denote $y_N = y_N^0 + y_N^1$, $y_S = y_S^0 + y_S^1 + T^i$, $\breve{y}_N = y_N^0 + \delta_N y_N^1$ and $\breve{y}_S = y_S^0 + \delta_S \left(y_S^1 + T^i \right)$. We can combine (4) and (6) to get rid of the permit price:

$$\sigma_N' \left(m_N \right) \left[y_N^0 + \delta_N y_N^1 \right] = \sigma_S' \left(m_S + T^m \right) \left[y_S^0 + \delta_S \left(y_S^1 + T^i \right) \right] \tag{11}$$

Differentiating this condition yields:

$$\sigma_N'' \breve{y}_N dm_N = \sigma_S'' \breve{y}_S \left[dm_S + dT^m \right] + \sigma_S' \delta_S dT^i \tag{12}$$

Differentiated the market clearing condition gives:

$$\sigma_N' y_N dm_N + \sigma_S' y_S \left[dm_S + dT^m \right] + \sigma_S dT^i = d\hat{e} \tag{13}$$

Together, (12)and (13) define a system in two endogenous variables dm_N and dm_S and several exogenous parameters T^i, T^m and $\hat{e}$. This can be written as:

$$\begin{cases} \sigma_N'' \breve{y}_N dm_N - \sigma_S'' \breve{y}_S dm_S = \sigma_S'' \breve{y}_S dT^m + \sigma_S' \delta_S dT^i \\ \sigma_N' y_N dm_N + \sigma_S' y_S dm_S = -\sigma_S' y_S dT^m - \sigma_S dT^i + d\hat{e} \end{cases} \tag{14}$$

The determinant of the coefficient matrix (left hand side of system) can be shown to be negative:

$$\det \mathbf{A} = \sigma_N'' \breve{y}_N \sigma_S' y_S - \left[-\sigma_S'' \breve{y}_S \right] \sigma_N' y_N = \sigma_N'' \sigma_S' \breve{y}_N y_S + \sigma_S'' \sigma_N' \breve{y}_S y_N < 0$$

We can now compute the comparative statics. We start with the impact of the global emission limit on the mitigation efforts:

(15) $$\frac{dm_N}{d\hat{e}} = \frac{1}{\det \mathbf{A}} \det \begin{bmatrix} 0 & -\sigma''_S \breve{y}_S \\ 1 & \sigma'_S y_S \end{bmatrix} = \frac{1}{\det \mathbf{A}} \sigma''_S \breve{y}_S < 0$$

(16) $$\frac{dm_S}{d\hat{e}} = \frac{1}{\det \mathbf{A}} \det \begin{bmatrix} \sigma''_N \breve{y}_N & 0 \\ \sigma'_N y_N & 1 \end{bmatrix} = \frac{1}{\det \mathbf{A}} \sigma''_N \breve{y}_N < 0$$

As expected, when the emission limit gets tougher, the mitigation efforts will be higher.

Regarding the impact of the mitigation support level on the mitigation effort, it can be shown that:

(17) $$\frac{dm_N}{dT^m} = \frac{1}{\det \mathbf{A}} \det \begin{bmatrix} \sigma''_S \breve{y}_S & -\sigma''_S \breve{y}_S \\ -\sigma'_S y_S & \sigma'_S y_S \end{bmatrix} = 0$$

(18)

$$\frac{dm_S}{dT^m} = \frac{1}{\det \mathbf{A}} \det \begin{bmatrix} \sigma''_N \breve{y}_N & \sigma''_S \breve{y}_S \\ \sigma'_N y_N & -\sigma'_S y_S \end{bmatrix} = \frac{1}{\det \mathbf{A}} \left[-\sigma''_N \breve{y}_N \sigma'_S y_S - \sigma''_S \breve{y}_S \sigma'_N y_N \right] = -\frac{\det \mathbf{A}}{\det \mathbf{A}} = -1$$

This gives us the following proposition:

<u>*Proposition 1:*</u> *When there is an international agreement regulating the emissions over both periods, a transfer of mitigation capital has no impact on the optimal mitigation level in the North, and completely crowds out mitigation in the South, unless a matching grant function is used.*

The result is intuitive. As the South receives mitigation capital from the North, it will reduce its own mitigation investments as this gives an opportunity for increased consumption. Since there is a fixed global cap on emissions, it will reduce its mitigation contribution by exactly the same amount. This is also seen from equation (4) where the optimal mitigation level for the South is the same as before for a given permit price. The mitigation support has no impact on the mitigation choice of the North as it has no impact on the financial flows in the permit market if the price is unaffected. By combining equations (9) and(17), we see that $dp/dT^m = 0$. Note, however, that this transfer increases the consumption in the South. This will be discussed in Section 5 below.

To understand the last part of the proposition, note that one way the North could increase mitigation in the South, would be to use a “matching grant” form of support; for each dollar the South spends on mitigation, the North would pay an additional τ^m dollars for mitigation measures in the South, This gives $\breve{m}_S = m_S\left[1+\tau^m\right]$, where $\breve{m}_S$ is the total mitigation capital level in the South.

Using this mitigation function, we can show that there is still crowding out but at a lower rate:

(19) $$d\breve{m}_S = dm_S\left[1+\tau^m\right] + m_S d\tau^m = 0 \quad \Rightarrow \quad dm_S \big/ d\tau^m = -m_S \big/ \left[1+\tau^m\right].$$

Hence, the effect of a slight increase of the matching grant *rate* (from say 10% to 11%) is a decrease in mitigation expenditure in the South of $-m_S\big/\left[1+\tau^m\right]$. In order to make this comparable to the effect of the direct grant (which is measured in monetary terms), we have to divide by m_S in (19). Therefore, the effect of a slight change in the matching grant is given by $-1\big/\left[1+\tau^a\right]\in\left[-1,0\right]$, showing that there is incomplete crowding out in the matching grant case.

An incomplete crowding out implies that more is spent on mitigation measures. However, unless there are exogenous constraints that only external assistance can overcome, this will not be the welfare maximizing allocation of resources from the perspective of the South as they would allocate resources differently without the matching grant restriction.

Turning to the impact of the productive capital support level on the mitigation effort, we find by differentiating the system(14):

$$(20) \qquad \frac{dm_N}{dT^i} = \det \mathbf{A} \det \begin{bmatrix} \delta_S \sigma'_S & -\sigma''_S \breve{y}_S \\ -\sigma_S & \sigma'_S y_S \end{bmatrix} = \det \mathbf{A} \left[\delta_S \sigma'_S \sigma'_S y_S - \sigma''_S \breve{y}_S \sigma_S \right]$$

$$(21) \qquad \frac{dm_S}{dT^i} = \det \mathbf{A} \det \begin{bmatrix} \sigma''_N \breve{y}_N & \delta_S \sigma'_S \\ \sigma'_N y_N & -\sigma_S \end{bmatrix} = \det \mathbf{A} \left[-\sigma''_N \breve{y}_N \sigma_S - \delta_S \sigma'_S \sigma'_N y_N \right] > 0$$

Hence South's mitigation effort increases in the productive capital support. The reason is that the support increases emissions, giving a demand for more abatement to fulfill the agreement.

The impact on the mitigation effort by firms in the North cannot be signed easily. The intuition for this is the following. Emissions of the South are driven both by their mitigation effort and by their output:
$de_S = d\left[\sigma_S \left(m_S \right) \left[y_S^0 + y_S^1 + T^i \right] \right] = \sigma'_S y_S dm_S + \sigma_S dT^i$. Because of the productive capital support, output and emissions increase (second term on the right hand side). But, as mitigation goes up, emissions go down as well (first term on the right hand side). The net effect on emissions is not clear a priori. If South's emissions go down [up] as a result of the productive capital transfer, the North can increase [decrease] its emissions (hence lower [increase] its mitigation effort) in order to satisfy the overall emission constraint.

A sufficient condition for the mitigation effort in the North to increase in the development assistance (T^i), is that $[\sigma'_S]^2 \delta_S y_S < \sigma_S \sigma''_S \breve{y}_S < \sigma_S \sigma''_S y_S$ (because $\delta_S < 1$) and therefore $[\sigma'_S]^2 \delta_S < \sigma_S \sigma''_S \Rightarrow \frac{\delta_S}{\sigma_S} < \frac{\sigma''_S}{[\sigma'_S]^2}$, see the Appendix. This condition requires that the South is on the flat part of its marginal abatement cost curve (MAC) where σ''_S is high and therefore $1/\sigma''_S$ (i.e., the slope of MAC) low. This is very likely since most developing countries have only just started to invest in mitigation effort. Thus, we can conclude that the mitigation effort in the North most likely will increase in development assistance. This gives us Proposition 2.

Proposition 2: *When there is an international agreement regulating the emissions over both periods, development assistance that increases output and emissions in the*

South will increase the mitigation effort in the South. The mitigation effort in the North is also likely to increase.

The equilibrium price of permits is determined by the intertemporal market clearing condition and allowing for unrestricted banking and borrowing of permits between periods:

$$(22)\qquad \begin{aligned} &e_N^0 + e_S^0 + e_N^1 + e_S^1 = \hat{e} \\ &\sigma_N\left(\tilde{m}_N(p^*)\right)\left[y_N^0 + y_N^1\right] + \sigma_S\left(\tilde{m}_S(p^*, T^i)\right)\left[y_S^0 + y_S^1 + T^i\right] = \hat{e} \end{aligned}$$

To determine the effect of the transfers on the equilibrium price of permits, we totally differentiate this market clearing condition.

$$(23)\qquad \sigma_N' \frac{\partial \tilde{m}_N}{\partial p} dp^* y_N + \sigma_S' \frac{\partial \tilde{m}_S}{\partial p} dp^* y_S + \sigma_S' \frac{\partial \tilde{m}_S}{\partial T^i} y_S^1 dT^i + \sigma_S dT^i = d\hat{e}$$

From which we confirm that

$$(24)\qquad \frac{dp^*}{d\hat{e}} = \frac{1}{\sum_{j=N,S} \sigma_j' \frac{\partial \tilde{m}_j}{\partial p} y_j} < 0,$$

that is, the equilibrium permit price decreases in total emissions as expected.

Further, we find that

$$(25)\qquad \frac{dp^*}{dT^i} = \frac{-\sigma_S' \frac{\partial \tilde{m}_S}{\partial T^i} y_S^1 - \sigma_S}{\sum_{j=N,S} \sigma_j' \frac{\partial \tilde{m}_j}{\partial p} y_j} \;,$$

which is more difficult to sign because of the counteracting positive and negative terms in the numerator as the effect on emissions in the South is indeterminate as discussed above. However, we know from the first-order condition of mitigation in the North (equation (9)) that $dp = \frac{p\sigma_N''}{-\sigma_N'} dm_N$. Thus, it follows directly that $\frac{dm_N}{dT^i} > 0$ will lead to a higher equilibrium price of emission permits, i.e., $\frac{dp}{dT^i} > 0$.

4. Adaptation in the South

We now turn to the adaptation decision by the South, to see how the adaptation in the region depends on transfers from the North. The maximization problem of the South is given by:

(26)

$$\begin{aligned}\max_{a_S} \quad U_S &= c_S^0 + \delta c_S^0 = y_S^0 - m_S - a_S + p\left[\hat{e}_S^0 - e_S^0\right] + \\ &\delta_S \left\{\left[1 - \left[1 - \alpha_S(a_S + T^a)\right] D_S(\hat{e})\right]\left[y_S^0 + T^i\right] + p\left[\hat{e}_S^1 - e_S^1\right]\right\} \\ &= y_S^0 - m_S - a_S + p\left[\hat{e}_S^0 - \sigma_S\left(m_S + T^m\right) y_S^0\right] + \\ &\delta_S \left\{\left[1 - \left[1 - \alpha_S(a_S + T^a)\right] D_S(\hat{e})\right]\left[y_S^1 + T^i\right] + p\left[\hat{e}_S^1 - \sigma_S\left(m_S + T^m\right)\left[y_S^1 + T^i\right]\right]\right\}\end{aligned}$$

The necessary first-order condition for a maximum (interior solution[13]) with respect to adaptation effort, a_S, is given by: $-1 + \delta_S \alpha_S' D_S\left[y_j^1 + T^i\right] = 0$. Thus, we get

(27) $$\delta_S \alpha_S'\left(a_S + T^a\right) D_S\left(\hat{e}\right)\left[y_S^1 + T^i\right] = 1$$

The optimal adaptation effort is found by equalizing the marginal benefits of adaption (the left hand side) and its marginal costs (the right hand side). The FOC determines

[13] Sufficient conditions for an interior solution are that the first unit of investment in adaptation has a very large effect on the residual damages ($\alpha_i'(0) = +\infty$) and that this effect vanishes for very large investments
($\lim_{a_i \to +\infty} \alpha_i'(a_i) = 0$).

adaptation effort as an implicit function of adaptation and productive investment and the global emission cap: $\tilde{a}_S\left(T^a, T^i, \hat{e}\right)$.

Totally differentiating condition (27) yields:

$$(28) \qquad \delta_S \alpha_S''\left[da_S + dT^a\right] D_S\left[y_S^1 + T^i\right] + \delta_S \alpha_S' D_S' d\hat{e} + \delta_S \alpha_S' D_S dT^i = 0$$

It follows straightforwardly that

$$(29) \qquad \frac{\partial}{\partial \hat{e}} \tilde{a}_S\left(\hat{e}, T^a, T^i\right) = \frac{da_S}{d\hat{e}} = \frac{-\alpha_S' D_S'}{\alpha_S''} > 0$$

A higher global cap on emissions will cause the South to adapt more as the marginal benefit to adaptation is more important.

If follows also that

$$(30) \qquad \frac{\partial}{\partial T^a} \tilde{a}_S\left(\hat{e}, T^a, T^i\right) = \frac{da_S}{dT^a} = -1 .$$

That is, additional adaptation support completely crowds out the South’s own adaptation effort. Direct adaptation support funded by the North does not lead to additional adaptation because the South decreases its own adaptation effort by the same amount. In the same way as for mitigation, additional adaptation support frees up resources that the South prefers to use for consumption. The reason for this is seen from the first order condition given by equation (27). Adaptation transfers do not address any exogenous constraints to adaptation but simply offer additional adaptation resources. But since the benefit from adaption is the same before and after the transfer, it will be optimal for the South to stick to its original adaptation level. Thus, this is in line with the literature discussed in the introduction claiming that the benefits of adaptation are excludable, so the poor region has the right incentives to adapt even before the transfer.

How does the crowding out of mitigation and adaptation efforts depend on our assumption of an intertemporal permit market? Note that the result for adaptation depends on a given level of accumulated emissions in the second period. That is, there is no external effect from additional output through emissions. However, an intertemporal permit market is not the only way to achieve this. The same effect could also be achieved through a given total emission quota in each period, or if the South considers itself sufficiently small, that is, takes the accumulated emissions as given. When it comes to mitigation, an international climate treaty is assumed in our model to give an incentive for mitigation. If the agents within the regions consider themselves sufficiently small, they would not have any incentive to mitigate without a treaty.[14] As long as there is a treaty, it will determine the optimal mitigation efforts of the regions. Thus, it does not matter if there is an intertemporal permit market or a given total emission quota in each period.

As for mitigation transfers discussed above, the North could increase the adaptation in the South, and thus reduce damage in the South, by again using a "matching grant" form of support. As before this would lead to incomplete crowding out, but as this gives a different allocation of resources than without the matching grant restriction, it would result in a welfare loss for the South.

This gives us the following proposition:

<u>Proposition 3:</u> *Adaptation capital transfer from the North to South will completely crowd out adaptation investments in the South, unless a matching grant support function is used, but this will not give the welfare maximizing allocation of resources for the South.*

To study the effect on adaptation of development assistance, it follows from (28) that

$$(31)\qquad \frac{\partial}{\partial T^i}\tilde{a}_S\left(\hat{e},T^a,T^i\right)=\frac{da_S}{dT^i}=\frac{\delta_S\alpha_S' D_S}{\delta_S\left[-\alpha_S''\right]D_S\left[y_S^1+T^i\right]}=\frac{\alpha_S'}{\left[-\alpha_S''\right]\left[y_S^1+T^i\right]}>0,$$

[14] As long as we disregard secondary benefits of mitigation following for example from less local pollution.

Hence, productive capital support leads to the desired result that the South increases its adaptation effort. Intuitively, by promoting GDP growth in the South, more value is at risk in the region due to climate change.[15] This gives an incentive to increase adaptation efforts. Note that this effect hinges on the assumption that damages are proportional to output, a standard assumption in economic studies as mentioned in Section 2. The result can be stated in a Proposition:

<u>Proposition 4:</u> *An increase in development assistance will increase the adaptation level of the South.*

As seen from Propositions 2 and 4, increasing development assistance that increases production in developing countries has a positive impact on both mitigation and adaptation effort in the developing countries. This is in contrast to climate finance that gives transfer of adaptation and mitigation capital. These results hinge on the assumption that development assistance has a positive effect on production in the poor countries, and that we do not have a complete crowding out of investments in real capital.[16] In our model, we have assumed that the investments in real capital are exogenous, so that the growth potential of development aid is not crowded out. Some studies suggest that aid does not necessary raise capital stocks in developing countries, and that the outcome depends on domestic policies and institutions, see e.g., Dollar and Easterly (1999); Easterly and Pfutze (2008), but there are also more optimistic views on the effects of development aid (e.g. Sachs (2005); see also Banerjee and Duflo (2011) on the micro-level benefits of aid).

Thus, while we have modeled the effect of aid in a simple way, we can conclude that as long as aid is given in a way that promotes growth (not complete crowding out), the effect on mitigation and adaptation effort in the developing countries will be positive.

5. The North's choices of adaptation and transfers

[15] In addition, higher income may lead to higher demand for climate protection, but we do not model this income effect.
[16] One way to model crowding out could be to have a "leakage" parameter on all transfers to South, including development assistance, but that would not change the conclusions.

To decide on its adaptation level and the transfers to the South, the North wants to maximize its intertemporal welfare function, given all restrictions from Section 2 and subject to its adaptation level (a_N) and transfers (T^a, T^i, T^m). The optimal mitigation level (m_N) as well as the permit price (*p*) are found in Section 3. From there we have:

(32)
$$\begin{aligned}
&p = p(\hat{e}, T^i, T^m), \quad \textit{where} \quad \frac{\partial p}{\partial T^i} \geq 0 \quad \textit{and} \quad \frac{\partial p}{\partial T^m} = 0 \\
&m_N = m_N(\hat{e}, T^i, T^m) \quad \textit{where} \quad \frac{\partial m_N}{\partial T^i} > 0 \quad \textit{and} \quad \frac{\partial m_N}{\partial T^m} = 0 \\
&m_S = m_S(\hat{e}, T^i, T^m) \quad \textit{where} \quad \frac{\partial m_S}{\partial T^i} > 0 \quad \textit{and} \quad \frac{\partial m_S}{\partial T^m} = -1 \\
&a_s = a_S(\hat{e}, T^a, T^i) \quad \textit{where} \quad \frac{\partial a_S}{\partial T^a} = -1 \quad \textit{and} \quad \frac{\partial a_S}{\partial T^i} > 0
\end{aligned}$$

The optimization problem for the North can then be written as

(33)

$$\begin{aligned}
\max_{a_N, T^a, T^i, T^m} U_N = &(1-\mu)\left(y_N^0 - m_N - a_N - T^a - T^i - T^m + p(\hat{e}_N^0 - \sigma_N(m_N)y_N^0)\right) \\
&+ \mu\left(y_S^0 - m_S - a_S + p(\hat{e}_S^0 - \sigma_S(m_S + T^m)y_S^0)\right) \\
&+ \delta_N \left[\begin{array}{l} (1-\mu)\left(y_N^1\left(1-(1-\alpha_N(a_N))\right)D_N(\hat{e}) + p(\hat{e}_N^1 - \sigma_N(m_N)y_N^1)\right) \\ +\mu\left((y_S^1 + T^i)\left(1-(1-\alpha_S(a_S + T^a))\right)D_S(\hat{e}) + p(\hat{e}_S^1 - \sigma_S(m_S + T^m)(y_S^1 + T^i))\right) \end{array}\right]
\end{aligned}$$

The Kuhn-Tucker conditions, where the choices of the South are taken as given, are

(34)
$$\frac{\partial U_N}{\partial a_N} = -(1-\mu) + (1-\mu)\delta_N y_N^1 D_N(\hat{e})\alpha_N' \leq 0$$

(35)
$$\frac{\partial U_N}{\partial T^a} = -(1-\mu) + \mu\delta_N\left(y_S^1 + T^i\right)D_S(\hat{e})\alpha_S'\left(\frac{\partial a_S}{\partial T^a} + 1\right) \leq 0$$

$$
\begin{aligned}
(36)\qquad \frac{\partial U_N}{\partial T^m} = &-(1-\mu)\left(\frac{\partial m_N}{\partial T^m}+1-\frac{\partial p}{\partial T^m}(\hat{e}_N^0-\sigma_N(m_N)y_N^0)+p\sigma_N'(m_N)\frac{\partial m_N}{\partial T^m}y_N^0\right)\\
&-\mu\left(\frac{\partial m_S}{\partial T^m}-\frac{\partial p}{\partial T^m}(\hat{e}_S^0-\sigma_S(m_S+T^m)y_N^0)+p\sigma_S'(m_N)\left(\frac{\partial m_S}{\partial T^m}+1\right)y_N^0\right)\\
&+\delta_N(1-\mu)\left(\frac{\partial p}{\partial T^m}(\hat{e}_N^1-\sigma_N(m_N)y_N^1)+p\sigma_N'(m_N)\frac{\partial m_N}{\partial T^m}y_{Ni}^1\right)\\
&+\delta_N\mu\left(\frac{\partial p}{\partial T^m}(\hat{e}_S^1-\sigma_S(m_S+T^m)y_N^1)+p\sigma_S'(m_N)\left(\frac{\partial m_S}{\partial T^m}+1\right)y_N^1\right)\le 0
\end{aligned}
$$

$$
\begin{aligned}
(37)\qquad \frac{\partial U_N}{\partial T^i} = &-(1-\mu)\left(\frac{\partial m_N}{\partial T^i}+1-\frac{\partial p}{\partial T^i}\cdot\left(\hat{e}_N^0-e_N^0\right)+p\sigma_N'\frac{\partial m_N}{\partial T^i}y_N^0\right)\\
&-\mu\left[\frac{\partial m_S}{\partial T^i}+\frac{\partial a_S}{\partial T^i}-\frac{\partial p}{\partial T^i}\cdot\left(\hat{e}_S^0-e_S^0\right)+p\sigma_S'\frac{\partial m_S}{\partial T^i}y_S^0\right]\\
&+\delta_N(1-\mu)\left(\frac{\partial p}{\partial T^i}\cdot\left(\hat{e}_N^1-e_N^1\right)-p\sigma_N'\frac{\partial m_N}{\partial T^i}y_N^1\right)\\
&+\delta_N\mu\left[\begin{array}{l}\left(1-\left(1-\alpha_S(a_s+T^a)\right)\right)D_S(\hat{e})+\left(y_S^1+T^i\right)\alpha_S'\dfrac{\partial a_S}{\partial T^i}D_S(\hat{e})\\ +\dfrac{\partial p}{\partial T^i}\cdot\left(\hat{e}_S^1-e_S^1\right)-p\sigma_S'\dfrac{\partial m_S}{\partial T^i}\cdot\left(y_S^1+T^i\right)-p\sigma_S(m_S+T^m)\end{array}\right]\le 0,
\end{aligned}
$$

where equality holds for interior solutions of the respective endogenous variables.

Before discussing the first order conditions, note that by setting $\mu = 0$, the only reasons for transfers from North to South would be strategic. Thus, ethical reasons such as “to do good” would not apply.

To find the optimal levels of adaptation and transfers, we need to work with the first-order condition. Let us start with the adaptation level. For $a_N > 0$, we see from (34) that

$$(38)\qquad 1=\delta_N y_N^1 D_N(\hat{e})\alpha_N^{'}$$

where the left hand side is the marginal cost of adaptation, while the right hand side is the discounted marginal benefits of adaptation. Equity considerations have no impact on the adaptation level in the North. The optimal adaptation level follows from economic considerations only. Thus, in this model, both the mitigation level and adaptation level of the North is unaffected by its equity preferences.[17] This gives the following proposition:

<u>Proposition 5:</u> *The mitigation and adaptation levels of the North are unaffected by its equity preferences. However, the mitigation level is affected indirectly by its equity preferences via the impact of the development transfers on the permit market, when there is an international emissions treaty.*

The first part of the proposition has been explained above. The last part of the proposition follows as mitigation in North depends on the permit price (equation (6)), and that the permit price is affected by the development transfer, see equation (25). Equation (37) shows how the development assistance varies with the equity parameter. This will be further discussed below.

For an interior solution of adaptation transfers, we find from (35):

$$(39) \qquad 1-\mu = \mu\delta_N \left(y_S^1 + T^i\right) D_S(\hat{e})\alpha_S' \left(\frac{\partial a_S}{\partial T^a} + 1\right)$$

This shows that the marginal cost of the transfer in the North, weighted with the equity weight (left hand side), should equal the benefit of increased consumption in the South in the next period, also weighted with the equity weight (right hand side). But from (32) we know that $\frac{\partial a_S}{\partial T^a} = -1$ and the adaptation transfer completely crowds out South's adaptation effort if there are no constraints to the transfer. In this case we see that (39) does not hold, and there is no interior solution. Thus, it will not be optimal for the North to transfer adaptation capital to the South.[18]

---

[17] One would think that equity preferences matter for adaptation as adaptation affects the consumption level in the North, and equity preferences go in the direction of a lower consumption level in this region. Note first that the consumption level in the South is not affected. However, while higher adaptation in the first period reduces consumption in the North, it increases northern consumption in the second period as damage then will be lower. The benefit of adaptation is weighted with the equity weight, and so is the cost. Thus, the weight does not affect the optimum.

[18] Note that an adaptation transfer in this case would be equal to a pure consumption transfer. As discussed in footnote 11, a consumption transfer will not be optimal with a linear utility function. Note, however, that with a concave utility function, we would get an interior solution, and it would be optimal with an adaptation transfer even if the adaptation level in the South did not increase. The

However, if there are constraints attached to the adaptation transfers, such that for every dollar used on adaptation in the South, the North transfers τ^a dollars (a matching grant), we know from Section 3 that there is crowding out, but it is not necessarily complete. Using a matching grant may, therefore, give an interior solution of the optimization problem and a positive adaptation transfer from the North to the South will occur. The magnitude of this transfer is increasing with the equity weight put on the utility of the South, and the transfer would be zero if the weight is set to zero. Thus, there is no strategic reason to transfer adaptation capital to the South; this is only done for equity reasons.

To study the optimal mitigation transfers, we combine (36) and (32) and find

$$(40) \qquad \frac{\partial U_N}{\partial T^m} = -(1-\mu) + \mu < 0$$

Thus, as for adaptation transfers, there is no interior solution to mitigation transfers and the optimal level is equal to zero. The mitigation transfer would just work as a consumption transfer, which is not optimal with the linear utility function.

This gives us the following proposition:

<u>Proposition 6:</u> *Due to the complete crowding out of adaptation and mitigation in the South from adaptation and mitigation transfers respectively, these would work as pure income transfers, which will not be optimal with a linear utility function. The transfers could be optimal if they are designed as a matching grant function.*

The optimal level of development assistance follows from equation (37). Assuming an interior solution, it can be re-organized as:

---

reason is that consumption in South would increase and the inequality between the two sectors would be lower. This would increase the utility of the North as they express inequality aversion.

$$
\begin{aligned}
(41)\qquad & -(1-\mu)-\frac{\partial m_N}{\partial T^i}\left[(1-\mu)\cdot\left(1+p\sigma_N'\cdot\left(y_N^0+\delta_N y_N^1\right)\right)\right] \\
& +\frac{\partial p}{\partial T^i}\left[(1-\mu)\cdot\left(\hat{e}_N^0-e_N^0+\delta_N\cdot\left(\hat{e}_N^1-e_N^1\right)\right)+\mu\cdot\left(\hat{e}_S^0-e_S^0+\delta_N\cdot\left(\hat{e}_S^1-e_S^1\right)\right)\right] \\
& -\frac{\partial m_S}{\partial T^i}\left[\mu\left(1+p\sigma_S'\cdot\left(y_S^0+\delta_N\cdot\left(y_S^1+T^i\right)\right)\right)\right] \\
& -\frac{\partial a_S}{\partial T^i}\left[\mu\left(1-\delta_N\cdot\left(y_S^1+T^i\right)\alpha_S' D_S(\hat{e})\right)\right] \\
& +\delta_N\mu\left[\left(1-\left(1-\alpha_S(a_s+T^a)\right)\right)D_S(\hat{e})-p\sigma_S\cdot(m_S+T^m)\right] \\
& =0
\end{aligned}
$$

As seen from(41), the development assistance has impacts on the utility of the North via changes in the permit price and the mitigation efforts in both countries, the adaptation level in the South as well as the income increase in the South as the region gets richer.

If $\mu = 0$, i.e., the North does not have any preferences about the welfare of the South, equation (41) turns into:

$$
(42)\qquad 1=\frac{\partial p}{\partial T^i}\left(\hat{e}_N^0-e_N^0+\delta_N\cdot\left(\hat{e}_N^1-e_N^1\right)\right)-\frac{\partial m_N}{\partial T^i}-\frac{\partial m_N}{\partial T^i}\,p\sigma_N'\cdot\left(y_N^0+\delta_N y_N^1\right)
$$

It follows from (42) that even if the North does not care about the welfare of the South, the region may still be interested in transferring development assistance for strategic reasons as the transfer has impacts on the financial flows from the permit market and its mitigation effort. The left hand side of the equation is the cost of giving one unit of development assistance, which is foregone consumption, while the right hand side describes the effects this transfer has on the North. The first term on the right hand side describes the change in financial flows from the permit market due to a change in the permit price. A higher permit price (see equation(32)) will be beneficial for North if it is a permit seller, while it will be the other way around if it is a buyer. Further, mitigation in North will increase ($\frac{\partial m_N}{\partial T^i} > 0$) and reduce consumption, but more mitigation also has a positive effect on the financial flows from the permit market as it reduces emissions in the North and therefore the need to buy permits ($p\sigma'_N \cdot \left(y_N^0 + \delta_N y_N^1 \right) < 0$). Thus, while there are no strategic reasons to transfer adaptation or mitigation capital in this model, there may be both strategic and ethical reasons to give development assistance to the poor region. This gives us the final Proposition:

<u>*Proposition 7:*</u> *While there are no strategic reasons to transfer mitigation and adaptation capital to the South, development assistance has a strategic element in addition to the equity aspects via the financial flows in the emission permit market and the need for mitigation effort.*

Note, however, that the strategic and ethical incentives may go in different directions. For instance, even if the North cares about the South, it may still refrain from transferring development assistance or reduce the ethically optimal level due to the effect of the transfer on its mitigation and the financial flows from the emission permit market.

7. Conclusions

This paper discusses the ethics of climate finance as a core element of global climate policy and a complement to development assistance. Financial transfers to support mitigation and adaptation are an important aspect of the international negotiations on climate change. However, from an ethical point of view the offer for climate finance has to be seen in a broader context of financial assistance to developing countries, which also includes official development assistance, as development aid may have implications for emissions and vulnerability to climate change in addition to promoting growth. Both official development assistance and the offer for future climate finance are of roughly similar orders of magnitude, about US$ 100 billion a year worldwide.

The paper explores three kinds of financial assistance: mitigation (to reduce emissions), adaptation (to become climate resilient) and development (to increase income). Since we are concerned with the equity aspects of these flows, the motivation for transfers is derived solely from the North’s concern about well-being in the South. Our model does not include any strategic reasons for mitigation and adaptation transfers, such as the need to secure a global agreement on emissions, or concerns about international trade, where countries specializing in an adaptation or mitigation technology may expand their market if others apply that technology. There are also no barriers to adaptation. Given the resources, the South is as adept in protecting itself against climate calamities as the North.

In the absence of market barriers or strategic concerns, development assistance turns out to be the most interesting transfer, assuming that the assistance is given in such a way that growth is promoted. As we have assumed linear utility functions in consumption, adaptation and mitigation transfers are less effective than development assistance, although this may change with a concave utility function in the North. More substantially, development assistance will increase the adaptation level of the South as higher production levels will mean more damage from climate change in the future. Further, when there is an international agreement regulating the emissions over both periods, development assistance that increases output and emissions in the South will increase the mitigation effort in the South, and emissions per unit of production will fall. The mitigation effort in the North will also most likely increase as a consequence.

We also find that both transfers of adaptation- and mitigation capital from the North to the South will completely crowd out similar investments in the South. They will not result in additional climate change action and work as pure consumption transfers only. This is because the marginal costs and benefits of neither adaptation nor mitigation are affected by the transfer, and the external benefits of mitigation (which would otherwise be distortionary) are fully internalized in the global carbon market.

To secure additional adaptation or mitigation action in the South, the transfers would have to occur in the form of a “matching grant”, that is, it would have to require equivalent investments from the South and thus alter the benefit-cost ratio of adaptation/mitigation in the region. In our model this constraint would not lead to a welfare maximizing allocation of resources. Matching grants could however be justified if the North cares particularly about climate security in the South, rather than welfare more broadly.

The mitigation and adaptation levels of the North itself are unaffected by its equity preferences. However, the mitigation level is affected indirectly via the impact of development assistance on the international carbon market.

The conclusion from this analysis is, therefore, that from a pure equity point of view – as long as there is a binding global emissions constraint and no other market imperfections – the most effective instrument for climate finance is a development transfer that promotes growth. It will increase adaptation and mitigation in the South alongside the consumption level. Thus, it may be efficient in achieving both intergenerational- and intragenerational equity as impacts of future climate change will be reduced and the consumption inequality between future generations will be smaller.

Our conclusions are similar to those of Kverndokk et al. (2012). They also apply the Fehr/Schmidt inequality aversion in consumption to study an optimal global climate treaty, and find that inequality aversion lifts the consumption path of the poor region, while it lowers the consumption path of the rich region, which must take a greater share of the climate burden.

Our findings relate to the widely held view, expressed most prominently by Schelling (1992, 1997) that economic development is the best way to reduce vulnerability to climate change (see also Bowen et al. 2012 for a more nuanced discussion). However, there is a subtle difference. The Schelling conjecture (echoed also by Lomborg, 2007) is based on an efficiency argument, while we argue from an equity point of view – and deliberately ignore many of the adaptation barriers that Schelling claims development can overcome.

In this and other respects, our model is quite simple, and some of the conclusions obviously depend on the assumptions. The assumptions of linear utility functions were commented on already. With concave utility functions, the option for the North would be to increase the Southern consumption by either transferring consumption goods directly, or transferring adaptation or mitigation capital. The choice would depend on transaction costs akin to the “leaky bucket” problem; i.e., efficiency loss in distribution. As a consequence, transferring adaptation or mitigation capital may give different effects on consumption and on who receives the consumption good than a direct transfer of the good itself.

The results depend on an international agreement that constrains global emissions, which we introduced to isolate the equity aspects of the problem. This may not be realistic for some years to come, even if climate finance should accompany a new international treaty from 2020. However, the cap on emissions does not need to be strict or environmentally optimal for the model to work. The assumption does not necessarily constrain emissions in the South as their emissions limit may be set equal to their business-as-usual level or even higher. Permit trading in this case could be seen as a Clean Development Mechanism-style transfer, where the North can avoid mitigation at home by paying for mitigation in the South.

The model could be extended in several directions. Output could be modeled as a function of the stock of productive capital and hence introducing an endogenous capital investment process. This would complicate the analyses considerably because both the mitigation and capital accumulation process would have to be modeled as the outcome of a non-cooperative game. We do not believe that the added complications would fundamentally affect the basic results derived in the simpler formulation.

A more interesting extension would be the introduction of market imperfections. So far, we have assumed that the South can chose its adaptation strategy without restriction. In reality however, capital market imperfections and other constraints are likely to restrain the adaptation potential in the South. It would be interesting to investigate how this might affect the results and maybe open up the possibility for other types of assistance (like subsidized loans and technical assistance). As a third extension, our non-cooperative Nash could be structured as an alternative game, such as a Stackelberg game with a leader and follower.

A fourth set of extensions would involve alternative ways of modeling the equity preferences of the North. One interesting option could be to study the historical responsibility case, where climate damages rather than the consumption level in the South enters North's utility function, or alternatively that the North only cares about the size of the transfers and not on the effect. Finally, we did not consider explicitly a social optimum of mitigation and adaptation. It would be interesting to study transfers that could secure an international climate treaty, although this is studied in several other papers as mentioned in the introduction. Implicitly, we could say that part of the optimal solution in our model lies in the appropriate choice of the overall emission ceiling $\hat{e}$. Given that we modeled the adaptation process as a private instead of public good, there is no market failure to be expected in adaptation. More sophisticated formulations are conceivable but are beyond the scope of this paper.

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Appendix: The effect of development assistance on mitigation in the North

The effect of an increase in productive capital in the South on the price and mitigation efforts cannot be signed. In particular,

$$\frac{dm_N}{dT^i}=\frac{\sigma'_S\delta_S-\dfrac{\sigma_S\sigma''_S\breve{y}_S}{\sigma'_S y_S}}{\dfrac{\sigma''_N\sigma'_S\breve{y}_S}{\sigma'_N}+\dfrac{\sigma'_N\sigma''_S y_N\breve{y}_S}{\sigma'_S y_S}}=\frac{\dfrac{[\sigma'_S]^2\delta_S y_S}{\sigma'_S y_S}-\dfrac{\sigma_S\sigma''_S\breve{y}_S}{\sigma'_S y_S}}{\dfrac{\sigma''_N\sigma'_S\breve{y}_S}{\sigma'_N}+\dfrac{\sigma'_N\sigma''_S y_N\breve{y}_S}{\sigma'_S y_S}}$$

A sufficient condition for the effect to be positive, is that

$\dfrac{[\sigma'_S]^2\delta_S y_S}{\sigma'_S y_S}-\dfrac{\sigma_S\sigma''_S\breve{y}_S}{\sigma'_S y_S}>0$, or $[\sigma'_S]^2\delta_S y_S<\sigma_S\sigma''_S\breve{y}_S<\sigma_S\sigma''_S y_S$ (since $\delta_S<1$) and therefore: $[\sigma'_S]^2\delta_S<\sigma_S\sigma''_S\Rightarrow\dfrac{[\sigma'_S]^2\delta_S}{\sigma_S}<\sigma''_S$. This condition requires that the South is on beginning or flat part of its marginal abatement cost curve (MAC) where σ''_S is high and therefore $1/\sigma''_S$ (i.e., the slope of MAC) low. This is very likely since most developing countries have only just started to invest in mitigation effort. We can, therefore, conclude that it is very likely that $\dfrac{dm_N}{dT^i}>0$, and because we know from the first order condition of mitigation in the North that $dp=\dfrac{p\sigma''_N}{-\sigma'_N}dm_N$, it follows directly that this will give a higher equilibrium price of emission permits, i.e., $\dfrac{dp}{dT^i}>0$.