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Department of Economics

10/2012

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July 2012

Publisher:
Helmholtz-Zentrum für Umweltforschung GmbH - UFZ
Permoserstr. 15
04318 Leipzig

ISSN 1436-140X

Which mode of funding developing countries' climate policies under the post-Kyoto framework?[1]

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This version: July 2012

Abstract. Funding developing countries' climate policies after Cancun (COP16) has a dual goal: firstly, to support mitigation of developing countries in order to sustain the two-degree pathway of stabilising the global mean temperature; secondly, to empower the vulnerable countries in low-income regions to adapt to and recover from the most adverse impacts of climate change. So far, the political and scientific discussion has mainly concentrated on the appropriate level of funding. Referring to the newly emerging climate finance architecture under the post-Kyoto framework, this paper argues that a stronger focus must be put on the question: which mode of funding to choose? This is for the reason that the currently discussed funding instruments, such as earmarking of industrialised countries' transfer payments to developing countries for reducing loss and damages, mitigation, or adaptation costs, may cause fundamental changes in the countries' strategic behaviour concerning mitigation and adaptation efforts. Moreover, some of the instruments fall short of a minimum requirement for the donors to voluntarily provide means, and thus cannot guarantee sustained funding. We develop our results in a non-cooperative two-country framework in which donor and recipient decide on mitigation in the first, and on adaptation in the second stage of the game.

JEL Classification: C72, D61, F35, Q54

Keywords: adaptation, climate policy, funding, mitigation, non-cooperative behaviour

Statement of exclusive submission:
This paper has not been submitted elsewhere in identical or similar form, nor will it be during the first three months after its submission to the Publisher.

[1] We have benefited from discussions at the Symposium "Governance of Adaptation" in Amsterdam, at a workshop of the Helmholtz Climate Initiative REKLIM (regional climate change) in Lüneburg and at research workshops at the European University Viadrina, Frankfurt (Oder), and the Helmholtz Centre for Environmental Research – UFZ, Leipzig. We also gratefully acknowledge financial support from the German Federal Ministry of Education and Research within its programme on 'Economics of Climate Change' FKZ 01LA1139A.

1. Motivation

The Conferences of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Cancun (COP16) and Durban (COP17) have finally put an end to the disconnected strands of previous international negotiations under the so-called Bali Plan of Action. This plan clearly distinguished short term action to mitigate climate change to be taken by industrialised countries until 2020, from similar long term efforts in developing and newly emerging economies. The latter group also included countries, which did not join or have recently withdrawn from the Kyoto Protocol, such as the United States and Canada. This new post-Kyoto architecture differs in many respects from the previous Kyoto regime. It links efforts in mitigation to efforts in adaptation and connects them to a comprehensive, worldwide system of monitoring, reporting and verification of greenhouse gas emissions. Moreover, it introduces a new international funding regime of voluntary financial pledges for these efforts, which is the focus of our paper.

The terms 'climate funding' or 'climate finance' within the academic literature (Glemarec 2011; van Melle et al. 2011) as well as among politicians and the public, refer to climate-related financial flows within or between countries that are dedicated to both mitigation and adaptation.[2] In this paper, we particularly focus on financial flows directed from industrialised to developing countries. Such flows are occasionally motivated by reasons of equity and fairness, evoking the fact that industrialised countries bear a distinctly higher 'historical responsibility' for climate change and its adverse effects compared to developing countries and newly emerging economies, such as China and India (Grasso 2010). More often, the flows are motivated by economic and political reasons within international negotiations (Abadie et al. 2012; Michaelowa and Michaelowa 2012).

1.1 A new architecture for international public climate finance under the post-Kyoto framework

The new architecture for international public climate finance emerging from the COP17 negotiations was preceded by a rudimentary finance architecture of the otherwise largely failed round of negotiations in Copenhagen in 2010 (COP15). The 'Copenhagen Accord' already provides for a 'fast-track finance' (FTF) and mentions (without detailing it) a track of 'long-term finance' (LTF) – the then called 'Copenhagen Green Fund', which was subsequently re-labelled in Cancun as 'Green Climate Fund' (GCF). FTF comprises immediate funding of $30 billion in the period 2010-2012 for adaptation and mitigation, but explicitly excludes funding for poverty alleviation and other development objectives, in order to be 'new and additional' to pre-existing funding from the Global Environmental Facility (GEF) of the World Bank and other Official Development Aid (ODA). The contributions to the FTF are voluntary 'pledges' to be communicated to the UNFCCC's secretariat in Bonn. LTF is only mentioned in the Copenhagen Accord as a programme to mobilise $100 billion per year by 2020 for the immense need for funding adaptation and mitigation measures in developing countries (IPCC 2007; Barrett 2008a). The 'Copenhagen Green Fund' was seen as the heart of LTF in the Copenhagen Accord, but the associated call for public and private sources, bilateral and multilateral channels, as well as 'alternative sources of finance' (e.g. insurance and derivatives for climate change 'loss and damages') already indicates the breadth of LTF in the negotiation context. In the following, we will be concerned with LTF in this comprehensive definition, without mere focus on the Green Climate Fund.

[2] IPCC (2007, Chapter 18.1.2) defines mitigation as any "anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases", while adaptation is defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities".

Glemarec (2011) has delivered a useful graphical representation, which depicts the possible new architecture for international public climate finance emerging from the COP17 negotiations (Figure 1). Climate finance will be implemented under the 'political' roof of the UNFCCC's negotiation process (COPs). As such, it will be part of the overall negotiation process. In practice, it will define the total amount of funding, set the rules for contributions and receipt of funding, and select a standing committee on finance to bundle the diverse efforts of LTF. The Green Climate Fund is at the heart of this funding scheme, but 'politically' connected in transparent ways to other existing UNFCCC funding streams, such as the so-called Adaptation Fund (AF), and parallel non-UNFCCC streams of funding, such as the GEF of the World Bank. These diverse lines of climate finance will be considered in the COP negotiations holistically, despite the fact that different UNFCCC and non-UNFCCC agencies are in charge for the programming, planning and budgeting of the funding schemes, e.g. the Word Bank's GEF agencies. Mitigation and adaptation shall be considered in the GCF 'in a balanced manner'. A new programme, decided in Durban, addresses residual 'loss and damages'.[3]

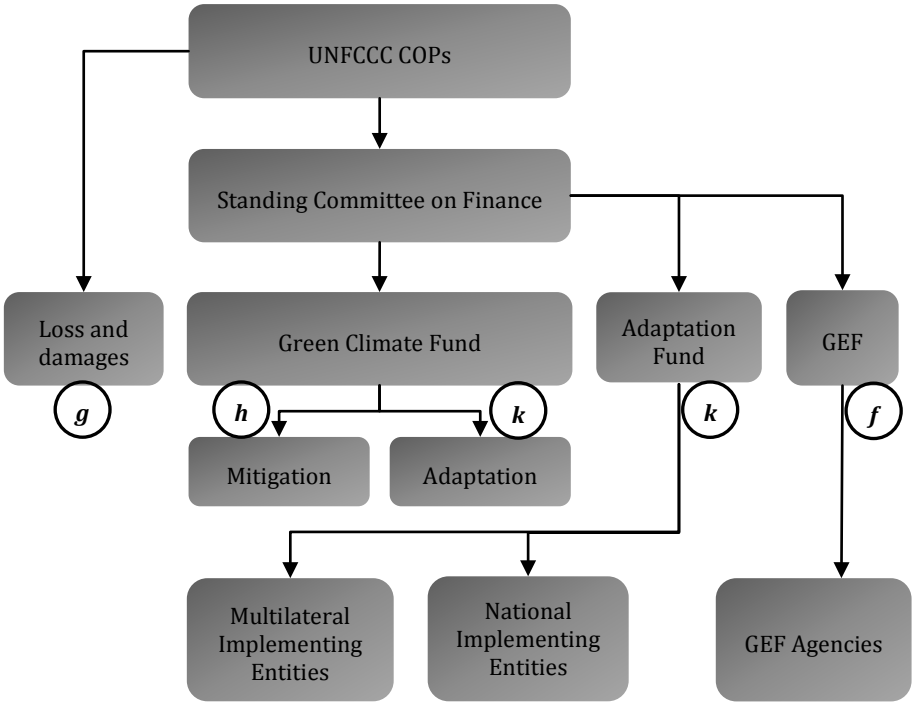

Figure 1: A new architecture for international public climate finance after the COP17 negotiations in Durban (Glemarec 2011, adjusted)

Most important to note for the following analysis is that the new architecture for climate finance basically provides four different modes of funding in terms of appropriation. The funding is either earmarked for reducing the developing countries' vulnerability, i.e. for reducing their potential damage costs, (f); their actual loss and damages, i.e. the funding serves as a kind of emergency relief, (g); their mitigation (h); or adaptation costs (k). The four letters f, g, h and k represent these different modes of funding in our model framework (see Section 3.1).

[3] It is included in a UNFCCC work programme for COP18 in Qatar as a follow up process to the Cancun Adaptation Framework (UNFCCC 2012, decision 1/CP.16, paragraphs 25-29).

1.2 Why does the mode of funding matter?

To date, both the political and scientific discussion have mainly concentrated on the appropriate level of funding. This paper scrutinises whether the so far neglected question which funding instrument to choose deserves closer attention. Our considerations build upon an emerging branch of literature, which addresses the new role of the adaptation option rooted in the post-Kyoto framework. Taking into account the absence of compulsory mitigation obligations within this framework, the respective contributions analyse the adaptation option's strategic implications and its interplay with the countries' decisions on mitigation in a non-cooperative framework.[4]

Auerswald et al. (2011) point out the basic strategic role of the adaptation option: by adapting to changing climatic conditions, a country reduces its associated (potential) residual damage which leads to an enhanced pay-off in the non-cooperative equilibrium. Consequently, the country improves its threat point within negotiations on international climate protection agreements and thus can influence the related burden sharing in its own interest. Moreover, the authors demonstrate that the presence of the adaptation option can, when combined with risk-averse preferences of the countries, induce a crowding-out effect in terms of mitigation. In this sense, a unilateral increase in mitigation would entail a constant or even increasing level in global emissions. Eisenack and Kähler (2012) show that this crowding-out effect may be reversed under certain cost constellations. Starting from these basic insights on the strategic dimension of the adaptation option, several contributions study the countries' optimal mix of mitigation and adaptation efforts with varying framework conditions and research priorities. Buob and Stephan (2011a) apply a model with several world regions having available a limited budget to be invested in mitigation and adaptation measures. They discover that the budget allocation crucially depends on the regions' initial endowment with respect to environmental quality and financial means. A special case of decision-making is studied by Barrett (2008b). He assumes that both mitigation and adaptation measures require some investments causing fixed costs which turn into sunk costs ex post. This constellation provokes corner solutions; in particular, countries solely invest in adaptation (mitigation) in case of non-cooperative (cooperative) behaviour. Zehaie (2009) introduces a static, non-cooperative framework comprising two countries, focussing on the role the sequence of the decision on mitigation and adaptation plays for the countries' strategic behaviour. Provided that the adaptation decision is timed before mitigation, countries engage in strategic adaptation in the following way. In the first stage, they render a higher adaptation effort in order to reduce their vulnerability and hence commit to a lower mitigation level in the second stage. This behaviour is driven by the intention to force the neighbour country to raise mitigation which in turn increases national welfare since mitigation is a public good. On the contrary, when mitigation is timed before adaptation, there is no scope for strategic behaviour since adaptation is a private good, for which reason there is no need to use mitigation as a commitment device. Consequently, this case is perfectly equivalent to simultaneous decision making. Ebert and Welsch (2012) apply a similar framework to study the impact of productivity, pollution sensitivity and adaptive capacity on the countries' emission and adaptation decisions. However, they restrict themselves to the case of adaptation being fixed after the decision on emissions, by arguing that the latter are indispensable for any economic activity and thus cannot be postponed after adaptation measures have been implemented.

[4] Only few contributions take for granted a given climate protection agreement and hence consider cooperative games of mitigation and adaptation. The focus here is on the adaptation option's impact on the agreement's stability and outcome in terms of global emissions (see e.g. Marrouch and Chaudhuri 2011; Benchekroun et al. 2011).

Other papers study institutional aspects of climate finance. Buob and Stephan (2011b) analyse the basic incentives for industrialised countries to contribute to adaptation funds. Pittel and Rübbelke (2011) demonstrate that adaptation funding increases the developing countries' fairness perception which in turn promotes their willingness to take part in international climate protection agreements.

However, to date there are, to the best of our knowledge, no studies which explicitly address the new climate finance architecture emerging under the post-Kyoto framework and the respective funding instruments. Our paper aims at closing this gap. Building upon the frameworks provided by Zehaie (2009) and Ebert and Welsch (2012), the four different modes of funding given in the post-Kyoto architecture are introduced. We demonstrate that the choice of funding instruments matters in two respects. Firstly, the instruments cause fundamental changes in the countries' strategic behaviour[5], which annihilate some important previously established results of Zehaie (2009), such as the equivalence of fixing mitigation before adaptation, and simultaneously with adaptation. Our second objective is to establish and validate a minimum requirement that sustains funding through the respective instrument. This is of particular relevance for climate finance policy as there are no considerable contributions to the track of long-term finance so far. Within the post-Kyoto climate finance architecture, funding is a unilateral voluntary measure of the industrialised country. Therefore, this country – except for the rare case of altruistic motives – will only approve transfer payments provided that it can draw some benefit from them. This is obviously only the case when funding induces the developing country to increase its mitigation effort. Due to its public-good character, mitigation is the only channel through which the industrialised country can profit in this respect – contrary to the private good of adaptation. As will be seen, some of the instruments do not meet this requirement and hence will not be capable of generating sustained financial support for developing countries. Following the argument of Ebert and Welsch (2012), we restrict our analysis to the case of mitigation being fixed before adaptation for the sake of conciseness.[6]

The rest of the paper is organised as follows. Section 2 introduces the basic model without funding, which is, in a first step, solved for the cooperative case, in order to achieve the globally efficient outcome as a benchmark. The subsequent analysis of the non-cooperative equilibrium basically reproduces the results derived by Zehaie (2009) and Ebert and Welsch (2012) in our framework. In Section 3, the funding instruments are introduced and investigated in terms of strategic effects and a minimum requirement for sustained finance. Finally, Section 4 presents some conclusions.

2. Basic results on the mitigation-adaptation mix

After introducing our economic framework (Section 2.1), the equilibrium mitigation-adaptation mix is derived both for the case of cooperative (Section 2.2), and for non-cooperative behaviour of countries (Section 2.3). The results serve as a reference point for studying the impacts of the various funding instruments, which will be introduced in Section 3. The cooperative and non-cooperative equilibrium outcomes will be compared in Section 2.4.

[5] In what follows, strategic behaviour is to be understood as any effort of a country in influencing the decision of its neighbour in order to increase own welfare or decrease own costs, respectively.

[6] Strictly speaking, Ebert and Welsch (2012) argue that emissions cannot be postponed after adaptation. Since, however, fixing the emission level similarly requires a decision on how much to mitigate, we can adopt their argument to rule out the case 'adaptation before mitigation'.

2.1 The Model

Consider a static world that is – following several related approaches (Hoel 1991; Zehaie 2009; Ebert and Welsch 2012) – assumed to comprise two countries $j = i, d$, where i denotes the industrialised and d the developing country. Each country may engage in mitigation (m_j) or adaptation (a_j) to decrease its exposure to the adverse impacts of climate change. Assume that the countries' mitigation efforts are perfect substitutes in reducing the (mean) global damage probability $p(m_i + m_d)$, with $p' < 0$. On the contrary, a country's adaptation effort exclusively reduces its own residual monetary damage $D_j(a_j)$, where $D_j' < 0$. Thus, there is the well-known contrast of mitigation being a public, and adaptation being a private good from the single country's perspective (see e.g. Füssel and Klein 2006). Moreover, we adopt the familiar assumptions that both mitigation and adaptation are subject to diminishing returns, i.e., $p'' > 0$, $D_j'' > 0$, and impose positive, increasing marginal costs on each country, i.e., individual mitigation and adaptation costs are given by $MC_j(m_j)$ and $AC_j(a_j)$, respectively, where $MC_j' > 0, MC_j'' > 0$ and $AC_j' > 0, AC_j'' > 0$. Note that the adaptation costs in this model have to be borne by the countries, no matter if a damage occurs or not. In other words, we do not consider responsive, but rather anticipatory adaptation measures (Smit et al. 1999).[7]

To sum up, a country's total expected costs associated with climate change, comprising the costs of mitigation and adaptation and expected damage costs, are

$$TC_j(m_i, m_d, a_j) = MC_j(m_j) + AC_j(a_j) + p(m_i + m_d)D_j(a_j). \quad (1)$$

By postulating a multiplicative relation between damage probability (depending on mitigation) and residual damage costs (depending on adaptation), the analysis can be kept tractable – in view of the diverse funding instruments to be introduced in Section 3 – and at the same time captures the public and private good character of mitigation and adaptation, respectively.[8] In what follows, we assume that the countries are risk neutral and minimise total expected costs.[9]

2.2 Cooperative equilibrium – global efficiency as a benchmark

In the benchmark case of cooperation, countries minimise global expected costs $GC = TC_i + TC_d$ and thus have full control of all variables. Consequently, the question of timing is not relevant since there is no gain to be made by deviating from the first-best solution (Zehaie 2009). The latter is obtained by minimising

$$GC = MC_i(m_i) + AC_i(a_i) + MC_d(m_d) + AC_d(a_d) + p(m_i + m_d)[D_i(a_i) + D_d(a_d)] \quad (2)$$

The first-order conditions with respect to m_j and a_j, $\forall j = i, d$, are

[7] Obviously, we could gain some additional results by also allowing for responsive adaptation measures causing costs only in case of damage. However, the main goal of this paper is to investigate the effects of the alternative funding instruments, which is why we refrain from this exercise.

[8] Note that we do not model (expected) damage costs as a single function depending on both mitigation and adaptation, i.e. $D_j = D_j(m_i + m_d, a_j)$, like for instance Ebert and Welsch (2012). Rather, we take a different approach similar to Kane and Shogren (2000) which disentangles the two strategic variables.

[9] Note that the minimisation of total expected costs is basically equivalent to the maximisation of expected welfare (see e.g. Heuson 2010).

$$MC_j' + p'[D_i(a_i) + D_d(a_d)] = 0, \tag{3}$$

$$AC_j' + p(m_i + m_d)D_j' = 0. \tag{4}$$

The system (3), (4) determines the globally optimal allocation of the countries' mitigation and adaptation efforts $(m_i{}^*, m_d{}^*, a_i{}^*, a_d{}^*)$. The first-order conditions clearly reflect the public and private good properties of mitigation and adaptation, respectively. The conditions for mitigation (3) state that each country's marginal cost of mitigation should equal the global marginal benefit of mitigation, which is given by the marginal decrease of the global damage probability multiplied by global damage costs. Thus, each country takes into account the positive externality of its own mitigation effort benefitting the neighbour country. On the contrary, marginal costs and benefits in case of adaptation are entirely private to the countries, as can be seen from (4).

2.3 Non-cooperative equilibrium

The calculation of the non-cooperative equilibrium within the basic model serves as a benchmark for studying the impacts of funding instruments in Section 3. In case there is no international cooperation, the sequence of the mitigation and adaptation decision is significant because it influences the countries' strategic incentives. For the reason stated above (Section 1.2), we restrict our analysis to the two-stage game where countries decide on mitigation in the first and on adaptation in the second stage. As shown by Zehaie (2009), this case is basically equivalent to fixing both strategic variables simultaneously. However, as will be seen in Section 3, this result cannot be sustained when funding in different modes is introduced. We adopt backwards induction and hence start out with solving stage two.

2.3.1 Stage two: fixing the adaptation level

Country j chooses a_j to minimise its total costs (1), taking m_i and m_d as exogenously given. This yields the following first-order condition with familiar meaning for either country

$$AC_j' + p(m_i + m_d)D_j' = 0, \forall j = i, d. \tag{5}$$

Since the neighbour country's adaptation choice is irrelevant to j's minimisation problem, (5) directly determines the countries' adaptation effort in the Nash equilibrium of stage two, given the mitigation levels resulting from stage one, $a_j(m_i, m_d)$. Hence, both countries have a dominant adaptation strategy. Moreover, mitigation and adaptation are substitutes in alleviating a country's expected damage costs, such that an increase in mitigation (no matter of which country) in the first stage entails a decrease in adaptation in the second stage: $\frac{\partial a_j}{\partial m_{i,d}} = -\frac{p'D_j'}{AC_j'' + pD_j''} < 0$.

2.3.2 Stage one: fixing the mitigation level

In stage one, country j minimises its total costs with respect to m_j, anticipating its equilibrium adaptation effort in stage two, $a_j(m_i, m_d)$:

$$TC_j(m_i, m_d) = MC_j(m_j) + AC_j\left(a_j(m_i, m_d)\right) + p(m_i + m_d)D_j\left(a_j(m_i, m_d)\right), \forall j = i, d. \tag{6}$$

The related first-order condition reads

$$MC_j' + p'D_j(a_j) = 0, \tag{7}$$

where $\frac{\partial TC_j}{\partial a_j} = 0$ is considered due to stage two.

To sum up, the allocation in the subgame perfect equilibrium $({m_i}^S, {m_d}^S, {a_i}^S, {a_d}^S)$ is implicitly given by the system (5), (7). Obviously, these are exactly the same first-order conditions that would result if mitigation and adaptation were fixed simultaneously (see Zehaie 2009). The reason is that there is no strategic interaction between countries in terms of adaptation in stage two, as shown above. Consequently, countries cannot benefit from using mitigation as a commitment device in stage one.

2.4 Cooperative vs. non-cooperative equilibrium

In this section, we underpin the well-known result that non-cooperative behaviour fails to achieve the first-best allocation when the provision of a public good is involved (Cornes and Sandler 1996). Comparing the equilibrium allocations in the cooperative, i.e. globally efficient and non-cooperative case yields:

Proposition 1 *Underprovision of mitigation as a public good.*
The efficient allocation $\boldsymbol{m}^* = ({m_i}^*, {m_d}^*)$ *and the subgame perfect equilibrium* $\boldsymbol{m}^S = ({m_i}^S, {m_d}^S)$ *are related to each other as follows:* $\boldsymbol{m}^* > \boldsymbol{m}^S$.

Proof: In the subgame perfect equilibrium, each country has a positive impact (externality) on its neighbour, i.e. $\partial TC_i / \partial\, m_d = p'D_i < 0$ and $\partial TC_d / \partial\, m_i = p'D_d < 0$, respectively. Thus, mitigation is suboptimally low. q.e.d.

Proposition 2 *Adaptation as substitute for mitigation.*
In the subgame perfect equilibrium, adaptation is higher compared to the efficient allocation: $\boldsymbol{a}^S > \boldsymbol{a}^*$.

Proof: As $\boldsymbol{m}^* > \boldsymbol{m}^S$, we know that $p^S > p^*$. Furthermore, for both efficiency and the non-cooperative behaviour, the optimal choice for adaptation is characterised by $AC_j'(a_j) + pD_j'(a_j) = 0$. Simple comparative statics imply $\frac{\partial a_j}{\partial p} = \frac{-D_j'}{AC_j'' + pD_j''} > 0$. q.e.d.

3. Funding developing countries' climate policies

In this section, we investigate how the alternative ways of funding promoted in the post-Kyoto process (which will be introduced in Section 3.1) influence the outcome in the non-cooperative equilibrium (Section 3.2). In a further step, we define a minimum requirement for sustained finance and validate it for the various funding instruments (Section 3.3).

3.1 Four types of 'open' funding

Referring to the new architecture for climate finance depicted in Section 1.1, there are basically four different types of funding to be considered in our framework in terms of appropriation (see Glemarec 2011):

i) Country i compensates the fraction $f \in [0; 1]$ of country d's potential damage costs. Thus, the funding amounts to $fD_d(a_d)$. This type of funding is rendered regardless of whether a damage occurs or not, i.e., the funding is vulnerability-related. Examples of respective funding can be found mainly in the Global Environmental Facility (GEF).[10]

ii) i compensates the fraction $g \in [0; 1]$ of d's expected damage costs. Thus, the expected funding amounts to $gp(m_i + m_d)D_d(a_d)$. This type of funding is to be understood as some kind of emergency relief since it is rendered only in case of damage, referring to the UNFCCC programme on loss and damages.[11]

iii) i compensates the fraction $h \in [0; 1]$ of d's mitigation costs. Thus, the funding amounts to $hMC_d(m_d)$. This type of funding refers to the UNFCCC policy programme of Nationally Appropriate Mitigation Actions (NAMA).[12]

iv) i compensates the fraction $k \in [0; 1]$ of d's adaptation costs. Thus, the funding amounts to $kAC_d(a_d)$. This type of funding can be found in the National Adaptation Programmes of Action (NAPAs) of the UNFCCC.[13]

We do not expand upon the question how the industrialised country finances the funding since this is not the focus of our paper. Rather, we simply assume that the funding is withdrawn from i's gross domestic product and hence increases its costs. Moreover, it is taken for granted that f, g, h and k are exogenous to the countries' decisions. Note that the four funding instruments are 'open' in two regards. First, the funding payment is not restricted to a certain amount, rather it captures a part of the developing countries' (potential or actual) damage, mitigation, or adaptation costs, respectively. Second, funding is a unilateral, voluntary measure of the industrialised country. By accepting the transfer payment, the developing country pledges itself to use the payment in the intended manner and to render the associated efforts in mitigation and adaptation. In this respect, we rule out any scope for moral hazard problems by assumption. Next, consider the countries' total costs depending on the four funding instruments,

$$TC_i = MC_i(m_i) + AC_i(a_i) + p(m_i + m_d)[D_i(a_i) + gD_d(a_d)] + fD_d(a_d) + hMC_d(m_d) + kAC_d(a_d), \quad (8)$$

[10] The GEF supports national sustainable development initiatives related to diverse environmental policies, including adaptation to climate change. The funding is channelled in accordance with the relative 'needs' of the recipient countries, i.e. greater for vulnerable than less vulnerable countries. Often it reflects wider development needs of these countries than mere costs of adaptation (Rübbelke and Ringel 2010). The GEF serves, on an interim basis, to operate the financial mechanism for the implementation of the UNFCCC, and shall continue to serve for the implementation of this convention if it is requested to do so by their Conferences of the Parties, which is currently much disputed – mainly by developing countries. The Second, Third and Fourth GEF Assemblies partly restructured the GEF in 2011 to improve the governance structure and thus reflect these concerns (GEF 2011).

[11] 'Loss and Damages' is currently a work programme under the UNFCCC as part of the Cancun Adaptation Framework. It will be a major focus of the upcoming COP18 in Qatar (UNFCCC 2012, decision 1/CP.16, paragraphs 25-29).

[12] Nationally Appropriate Mitigation Actions of Non-Annex I Parties to the UNFCCC were conceptually introduced in 2007, as part of the Bali Action Plan UNFCCC (2008a, p3). It came to the forefront of international negotiations as part of the Copenhagen Accord (UNFCCC 2010, decision 2/CP.15, p4), and was further elaborated in the Cancun Agreement (see UNFCCC 2011).

[13] National Adaptation Programmes of Action provide funding for least developed countries in priority activities for their urgent and immediate needs to adapt to climate change (UNFCCC 2008b).

and

$$TC_d = [1-h]MC_d(m_d) + [1-k]AC_d(a_d) + \big[[1-g]\,p(m_i + m_d) - f\big]D_d(a_d). \tag{9}$$

It is important to see that each funding instrument is tested separately whether it is target oriented. However, we introduce all instruments at the same time in our model in order to condense the analysis. The effect of each single instrument will be studied using comparative statics so that the impacts of all other instruments are automatically eliminated.

3.2 Non-cooperative equilibrium with funding

This section demonstrates that the equivalence of timing the decision on mitigation before adaptation, and simultaneously with adaptation (Zehaie 2009) does not persist when transfers through a funding mechanism are introduced.

3.2.1 Stage two: fixing the adaptation level

The countries' minimisation of (8) and (9) with regard to a_i and a_d, respectively, yields the following first-order conditions:

$$AC_i' + p(m_i + m_d)D_i' = 0, \tag{10}$$

$$[1-k]AC_d' + \big[[1-g]p(m_i + m_d) - f\big]\,D_d' = 0. \tag{11}$$

With perfectly analogous reasoning to the case without funding (Section 2.3.1), both countries choose adaptation in dominant strategies. Consequently, i's Nash equilibrium effort of stage two directly follows from (10), and d's effort from (11): $a_i(m_i, m_d)$, $a_d(m_i, m_d, f, g, k)$.

As in Section 2.3.1, it can be shown that first-stage mitigation – no matter of which country – decreases both country i's and d's second-stage adaptation: $\frac{\partial a_i}{\partial m_{i,d}} = -\frac{p'D_i'}{\partial^2 TC_i/\partial {a_i}^2} < 0$, $\frac{\partial a_d}{\partial m_{i,d}} = -\frac{[1-g]p'D_d'}{\partial^2 TC_d/\partial {a_d}^2} < 0$, where the denominator in both cases is positive due to the second-order condition.

Since country i cannot influence its additional costs raised by the various funding instruments through changing its adaptation effort, its equilibrium adaptation neither depends on f, g, h nor k. However, things are different for the developing country. Applying the implicit function theorem to (11) reveals the following relations:

$$\frac{\partial a_d}{\partial \cdot} = \frac{1}{\partial^2 TC_d/\partial {a_d}^2} * \begin{cases} D_d' & < 0 \\ p(m_i + m_d)D_d' & < 0 \\ 0 & = 0 \\ AC_d' & > 0 \end{cases} \text{ for } \begin{matrix} f \\ g \\ h \\ k \end{matrix}. \tag{12}$$

In case of an increase in f and g, respectively, the industrialised country compensates a larger part of the developing country's (expected) residual damage, leading to a lower marginal benefit of d's adaptation and thus $\partial a_d/\partial f < 0, \partial a_d/\partial g < 0$. On the contrary, an increase in k shrinks d's effective

marginal adaptation costs and thus implies $\partial a_d/\partial k > 0$. Naturally, the compensation of mitigation costs given by h does not impinge on d's adaptation decision, i.e. $\partial a_d/\partial h = 0$.

3.2.2 Stage one: fixing the mitigation level

In stage one, both countries anticipate the second-stage equilibrium by inserting $a_i(m_i, m_d)$ and $a_d(m_i, m_d, f, g, k)$ into equations (8) and (9). The first-order condition for cost minimisation reads for the industrialised country

$$MC_i' + p'[D_i(a_i) + gD_d(a_d)] + \frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i} = 0, \tag{13}$$

since $\frac{\partial TC_i}{\partial a_i} = 0$ is considered due to the second stage. Moreover, we have

$$\frac{\partial TC_i}{\partial a_d} = [gp(m_i + m_d) + f]D_d' + kAC_d' \begin{cases} < 0 & f \\ < 0 & g \\ = 0 & h \\ > 0 & k \end{cases} \text{ for } . \tag{14}$$

This gives rise to:

Proposition 3 *Strategic mitigation of the industrialised country in case of funding.*
Due to funding, the industrialised country engages in strategic mitigation, being reflected by $\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i}$ *within (13), as follows:*

i) Funding instruments f *and* g *induce* i *to decrease its mitigation effort, i.e.* $\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i} > 0$.

ii) Funding instrument h *provides no incentives for strategic mitigation, i.e.* $\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i} = 0$.

iii) Funding instrument k *induces* i *to increase its mitigation effort, i.e.* $\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i} < 0$.

Proof: Directly follows from (13), (14) and $\frac{\partial a_d}{\partial m_i} = -\frac{[1-g]p'D_d'}{\partial^2 TC_d/\partial {a_d}^2} < 0$.

These results can be explained as follows (see also Figure 2 below): The instruments f and g make i's total costs depending on d's damage. Thus, i can reduce its costs by inducing d to raise its adaptation effort, which can be done by lowering m_i, since $\frac{\partial a_d}{\partial m_i} < 0$. In other words, f and g reduce i's marginal benefit of mitigation for any m_i, i.e. the respective function is shifted inwards compared to the case without funding (here the function is $-p'D_i(a_i)$). Since i's marginal costs of mitigation are not affected by the funding instruments, this necessarily leads to a decrease in m_i for strategic reasons.[14] Instrument k makes i's costs depending on d's adaptation costs. These can be reduced by inducing d to decrease its adaptation effort which implies increasing m_i. Hence, k leads to an outwards shift of i's marginal mitigation benefits. Obviously, there is no way to strategically use m_i for reducing the costs i has to bear due to h.

[14] Besides inducing i to decrease its mitigation effort for strategic reasons, i.e. in order to influence d's decision on adaptation such that $\partial TC_i/\partial a_d < 0$, g provides an additional, non-strategic incentive to raise m_i in order to reduce p since the transfer payment is only due in case of damage. Thus, the overall impact of g on m_i is ambiguous at first glance. Since, however, this impact is not of interest for the further analysis, we abstain from elaborating on the sign of $\partial m_i/\partial g$.

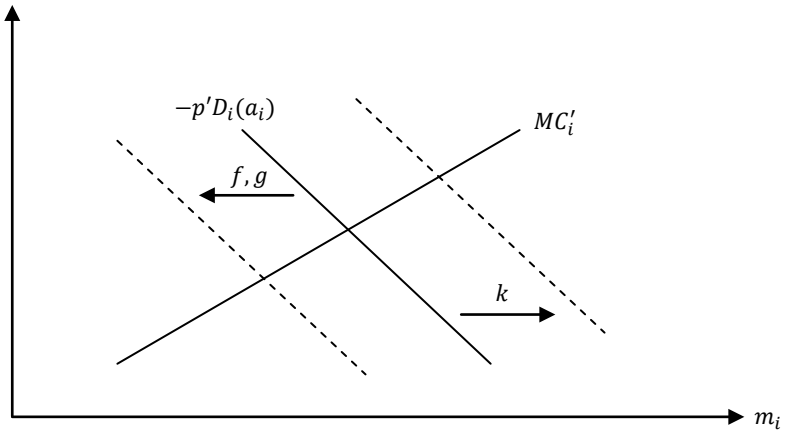

Figure 2: Strategic mitigation of the industrialised country in case of funding

The developing country's minimisation yields

$$[1-h]MC_d' + [1-g]p'D_d(a_d) = 0, \tag{15}$$

since $\frac{\partial TC_d}{\partial a_d} = 0$ is considered due to the second stage. Contrary to the industrialised country, d has no incentive for strategic mitigation since its costs do not depend on i's adaptation effort. Analogously to the case without funding (Section 2.3.2), the subgame perfect equilibrium allocation $({m_i}^S, {m_d}^S, {a_i}^S, {a_d}^S)$ is determined by the system (10), (11), (13), (15). Note that each of the equilibrium levels of adaptation and mitigation is a function of f, g, h and k, respectively.

3.3 Evaluation of the funding instruments' capability of providing sustained finance

After having studied the funding instruments' basic strategic impacts on the countries' mitigation and adaptation decisions, the question arises whether some policy recommendations can be deduced on which mode of funding to choose. In this respect, we restrict our analysis to a minimum requirement that guarantees the instruments' capability of providing sustained finance and hence, if not met, justifies ruling out the respective instrument from the beginning. To define this minimum requirement, it is first of all important to recognise that funding within the post-Kyoto architecture for climate finance is primarily a voluntary act on the part of the industrialised country. Consequently, the latter will not render any transfer payment without drawing at least some benefit out of it, given that we abstain from the improbable case of purely altruistically motivated action. Since the benefit of adaptation is entirely private to the countries, the only possible channel for transferring benefits from the developing to the industrialised country is through the positive externality of mitigation. Thus, a funding instrument needs to be attractive even for the industrialised country, which implies that it induces the developing country to increase its mitigation effort. Otherwise, the instrument fails to generate sustained financial support and hence necessarily falls short of the intended boost to global climate change policy efforts. To sum up, a minimum requirement to be fulfilled for generating sustained finance through any funding instrument (and equally for choosing any instrument at all) is the instrument's capability of inducing the developing country to raise its mitigation effort in the subgame perfect equilibrium compared to the case without funding. Validating this requirement for the four instruments at hand yields the following results:

Proposition 4 *Minimum requirement for the choice of funding instruments.*

i) *Funding instrument f proves to fulfil the requirement provided that the marginal damage probability is more elastic than d's damage costs in terms of i's mitigation, i.e. $\frac{\partial {m_d}^S}{\partial f} > 0$ for $|\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}|$.*

ii) *The results on funding instrument g are ambivalent, i.e. $\frac{\partial {m_d}^S}{\partial g}$ has no unambiguous sign.*

iii) *Funding instrument h proves to fulfil the requirement in any case, i.e. $\frac{\partial {m_d}^S}{\partial h} > 0$.*

iv) *Funding instrument k proves to fall short of the requirement provided that the marginal damage probability is more elastic than d's damage costs in terms of i's mitigation, i.e. $\frac{\partial {m_d}^S}{\partial k} < 0$ for $|\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}|$.*

Proof: Appendix.

These results can be explained as follows. The vulnerability-related funding, f compensates a part of d's damage costs and thus reduces d's marginal benefit of adaptation. Consequently, this leads to a higher level of m_d because d will substitute adaptation through mitigation. However, the strategic decrease in i's mitigation effort (see Proposition 3) additionally influences d's decision on m_d in terms of two contrary effects. First, it raises the global damage probability and thus, also d's expected damage costs. Second, it induces d to raise its adaptation effort, which in turn decreases d's expected damage costs. Provided that the first effect outweighs the second, which is the case when the marginal damage probability reacts more sensitively to a marginal increase in m_i than d's damage costs, i.e. $|\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}|$, i's strategic mitigation results in an overall increase in d's expected damage costs. Thus, the strategic mitigation reinforces d's incentive to render a higher mitigation effort. In the opposite case, given by $|\varepsilon_{p',m_i}| < |\varepsilon_{D_d,m_i}|$, i's strategic mitigation decreases the expected damage costs of the developing country and thus allows the latter for reducing m_d. Basically, g's impact on m_d is driven by the same effects that emerge from vulnerability-related funding (f). However, there is one crucial difference. Since g addresses, contrary to f, not potential but rather expected damage costs, it reduces both D_d and p and thus provides an additional incentive for d to render a lower mitigation effort, which is not given in case of f. This additional effect, taken together with all other effects triggered by f does not allow for providing a clear-cut result on g's impact on m_d. Thus, instrument g is inferior to f. In contrast to f and g, instrument h clearly fulfils the minimum requirement for sustained finance. By compensating a part of d's mitigation costs, it provides a direct incentive for d to render a higher mitigation effort. There are no other potentially reverse effects since h does not give rise to strategic mitigation on the part of i. Finally, the condition for instrument k to be rejected is exactly the opposite compared to f. That is because k, contrary to f, compensates a part of d's adaptation costs and hence induces d to substitute mitigation through adaptation and, moreover, causes a strategic increase in mitigation on the part of i (see Proposition 3). Building upon this, the rejection of k in case of $|\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}|$ immediately follows from the line of argument used for f.

To sum up, it can be stated that h is the superior mode of funding in terms of sustained finance. Moreover, it is reasonable to assume that $|\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}|$ because usually the direct effect of i's mitigation on the marginal damage probability outweighs the indirect effect on d's damage costs via a_d. Consequently, f fulfils the minimum requirement for being chosen in opposition to k.

Finally, validating the requirement with respect to g yields ambiguous results. Thus, this mode of funding is inferior to f and h.

4. Conclusion

It is widely accepted that there is a massive need for an increased funding of developing countries' climate policies – not only in order to reach a sufficient global level of mitigation for sustaining the two-degree pathway, but also in order to allow for adaptation measures that allay the most adverse impacts of climate change in low-income regions (van Melle et al. 2011). Starting from the newly emerging post-Kyoto climate finance architecture, which basically comprises four different modes of funding with respect to appropriation (the transfer payment is either earmarked for the compensation of potential damage costs, actual loss and damages, mitigation or adaptation costs), we argue that the political and scientific discussion should not merely focus on the appropriate level of funding, but rather also address the question which mode of funding to choose.

This paper makes, to the best of our knowledge, the first attempt to scrutinise and demonstrate the relevance of this question with game theoretical methods. Particularly, we adopt a non-cooperative framework in which the industrialised (donor) and developing country (recipient) decide on mitigation and adaptation in a sequential game. By focussing on the case of mitigation being fixed before adaptation, we show that the mode of funding matters in two respects. In the first place, the introduction of the funding instruments reverses some well-established results on the countries' strategic behaviour (see Zehaie 2009). In particular, the instruments induce the donor to engage in strategic mitigation and hence annihilate the so far presumed equivalence of deciding on mitigation before adaptation, and simultaneously with adaptation (see Ebert and Welsch 2012). Second, since funding is carried out on a voluntary basis, it has to be validated whether the funding instruments are in line with the donor's interest. If this is not the case, the instruments fail to generate sustained financial support for developing countries and hence should be ruled out from the beginning. In this respect, a minimum requirement for the choice of funding instruments is their capability of inducing the recipient to raise its mitigation effort, because there is no other way that the donor benefits from rendering the transfer payment. Seeing, that to date, there are no (noteworthy) contributions to the track of long-term finance comprising the four above-mentioned instruments, a careful examination of the donor's motives is of particular interest for climate finance policy. Our analysis shows that funding of mitigation, and potential damage costs, fulfil the aforesaid minimum requirement for providing sustained finance, contrary to adaptation-cost funding, which consequently should be rejected. Finally, validating the minimum requirement with respect to funding of actual loss and damages yields ambiguous results. Thus, this mode of funding is inferior to those fulfilling the minimum requirement.

Obviously, the current model framework concentrates on the most basic elements for scrutinising the post-Kyoto climate finance instruments for non-cooperative behaviour and hence offers various possibilities for extensions and further research. First, there is scope for variations in the general model framework that would clearly also be worth investigating beyond questions of climate finance, but of course similarly have significant impacts concerning the funding instruments. For instance, one could challenge the substitutability of mitigation and adaptation in terms of reducing expected damage costs (Proposition 2) along the lines of Buob and Stephan (2011a) and Parry et al. (2001). They argue that mitigation slows down climate change and thus allows societies for gaining time, which in turn can reduce the costs of adaptation. In this sense, there might be complementarity

between mitigation and adaptation which would of course fundamentally change the countries' strategic behaviour and the respective effects of the funding instruments. Another assumption to be questioned is that the benefits of adaptation are entirely private, since there might be some long-term effects of the developing countries' adaptation benefitting the industrialised countries. The resulting decrease in the developing countries' vulnerability might for instance prevent potential climate refugees from migration to industrialised countries and avoid associated conflicts. In this respect, the developing countries' adaptation would be a public good which gives rise to a new dimension of strategic behaviour on the part of the industrialised countries.

Second, there is scope for further research, particularly related to questions of climate finance. In the first place, it seems natural to deal with a group of industrialised and a group of developing countries rather than considering a two-country-world. On the one hand, this causes problems of free-riding among the industrialised countries concerning the provision of funds. On the other hand, a common-pool problem emerges on the part of the developing countries in terms of sharing the transfer payments. In each case, there is a need for institutionalisation, i.e. for establishing and enforcing rules of funding and sharing in order to overcome these problems. However, this in turn causes transaction costs which undermine the efficacy of the funding instruments. Observing that the long-term success of funding crucially depends on the incentives for becoming a donor country, it certainly makes sense to think about more sophisticated funding instruments that grant the donors additional benefits, beyond an increased contribution to mitigation through the recipients. For instance, the compensation of the developing countries' mitigation or adaptation costs could be tied to the transfer of related technologies stemming from the industrialised countries. Finally, in the mid- to long-term perspective, the question arises whether the loose relation between donor and recipient could be advanced to a contractual agreement, which allows both for a Pareto-improvement of the participating countries and guarantees an increased global mitigation effort. Consequently, it is an urgent task for future research to scrutinise the conditions for success of post-Kyoto agreements.

Appendix: Proof of Proposition 4

First of all, recapitulate the results following from the comparative statics at stage 2 (see Section 3.2.1):

$$\frac{\partial a_i}{\partial m_i} = \frac{\partial a_i}{\partial m_d} < 0 \text{ and } \frac{\partial a_d}{\partial m_i} = \frac{\partial a_d}{\partial m_d} < 0 \tag{A.1}$$

Then define the industrialised and developing country's first-order conditions with respect to mitigation as (see (13) and (15) in Section 3.2.2)

$$\begin{aligned} Z^i &:= MC_i' + p'[D_i(a_i) + gD_d(a_d)] + \frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i} = 0, \\ Z^d &:= [1-h]MC_d' + [1-g]p'D_d(a_d) = 0, \end{aligned} \tag{A.2}$$

with $\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i} = \left[[gp(m_i + m_d) + f]D_d' + kAC_d'\right]\frac{\partial a_d}{\partial m_i}$.

Differentiating (A.2) with respect to m_i and m_d yields

$$Z^i_{m_i} = MC_i'' + p''[D_i(a_i) + gD_d(a_d)] + p'\left[D_i'\frac{\partial a_i}{\partial m_i} + gD_d'\frac{\partial a_d}{\partial m_i}\right] + \underbrace{\frac{\partial\left(\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i}\right)}{\partial m_i}}_{\approx 0},$$

$$Z^i_{m_d} = p''[D_i(a_i) + gD_d(a_d)] + p'\left[D_i'\frac{\partial a_i}{\partial m_d} + gD_d'\frac{\partial a_d}{\partial m_d}\right] + \underbrace{\frac{\partial\left(\frac{\partial TC_i}{\partial a_d}\frac{\partial a_d}{\partial m_i}\right)}{\partial m_d}}_{\approx 0},$$

$$Z^d_{m_i} = [1-g]p''D_d(a_d) + [1-g]p'D_d'\frac{\partial a_d}{\partial m_i},$$

$$Z^d_{m_d} = [1-h]MC_d'' + [1-g]p''D_d(a_d) + [1-g]p'D_d'\frac{\partial a_d}{\partial m_d}. \qquad \text{(A.3)}$$

Differentiating (A.2) with respect to f, g, h, and k yields

$$Z^i_{\cdot} = \begin{cases} D_d'\frac{\partial a_d}{\partial m_i} & f \\ p'D_d + pD_d'\frac{\partial a_d}{\partial m_i} & g \\ 0 & h \\ AC_d'\frac{\partial a_d}{\partial m_i} & k \end{cases} \quad \text{for} \quad \text{and}$$

$$Z^d_{\cdot} = \begin{cases} 0 & f \\ -p'D_d & g \\ -MC_d' & h \\ 0 & k \end{cases} \quad \text{for} \quad . \qquad \text{(A.4)}$$

In order to validate the minimum requirement for sustained funding for the various instruments, we are interested in their impact on the developing country's mitigation effort in the subgame perfect equilibrium which is determined by the following system (see Sydsaeter et al. 2008):

$$\begin{pmatrix}\partial m_i \\ \partial m_d\end{pmatrix} = \frac{-\begin{pmatrix} Z^d_{m_d} & -Z^i_{m_d} \\ Z^d_{m_i} & Z^i_{m_i}\end{pmatrix}\begin{pmatrix} Z^i_{\cdot} \\ Z^d_{\cdot}\end{pmatrix} d\cdot}{\det}. \qquad \text{(A.5)}$$

Here, 'det' denotes the determinant of the numerator's matrix which origins from the countries' minimisation problem in terms of mitigation (see Section 3.2.2). Note that $\det > 0$ holds for a stable and unique Nash equilibrium in mitigation, which is determined by the system (A.2) (Tirole 1988). Calculating (A.5) for the respective instruments yields the following results:

Instrument f:

$$\frac{\partial m_d}{\partial f} = \frac{Z^d_{m_i} D_d'\frac{\partial a_d}{\partial m_i}}{\det} = \underbrace{\frac{D_d'\frac{\partial a_d}{\partial m_i} D_d p'}{\det m_i}}_{<0}\left[\underbrace{\varepsilon_{p',m_i}}_{<0} + \underbrace{\varepsilon_{D_d,m_i}}_{>0}\right], \qquad \text{(A.6)}$$

with $\varepsilon_{p',m_i} = \frac{\partial p'}{\partial m_i}\frac{m_i}{p'}$ and $\varepsilon_{D_d,m_i} = \frac{\partial D_d}{\partial a_d}\frac{\partial a_d}{\partial m_i}\frac{m_i}{D_d}$. Thus, we have $\frac{\partial m_d}{\partial f} > 0$ for $\left|\varepsilon_{p',m_i}\right| > \left|\varepsilon_{D_d,m_i}\right|$.

Instrument g:

$$\frac{\partial m_d}{\partial g} = \frac{Z^d_{m_i}\left[p' D_d + pD'_d \frac{\partial a_d}{\partial m_i}\right] + Z^i_{m_i} p' D_d}{\det} = \underbrace{\frac{p' D_d}{\det}}_{<0} \left[\left[\underbrace{\varepsilon_{p',m_i}}_{<0} + \underbrace{\varepsilon_{D_i+D_d,m_i}}_{>0} \right] \underbrace{\frac{[D_i+D_d]p'}{m_i}}_{<0} + \underbrace{MC_i''}_{>0} \right]$$
$$+ \underbrace{\frac{pD'_d \frac{\partial a_d}{\partial m_i}[1-g] D_d p'}{\det m_i}}_{<0} \left[\underbrace{\varepsilon_{p',m_i}}_{<0} + \underbrace{\varepsilon_{D_d,m_i}}_{>0} \right], \tag{A.7}$$

with $\varepsilon_{D_i+D_d,m_i} = \frac{\partial (D_i+D_d)}{\partial m_i} \frac{m_i}{D_i+D_d}$. Thus, $\frac{\partial m_d}{\partial g}$ has no unambiguous sign.

Instrument h:

$$\frac{\partial m_d}{\partial h} = \frac{\overbrace{Z^i_{m_i}}^{>0} \overbrace{MC'_d}^{>0}}{\underbrace{\det}_{>0}} > 0. \tag{A.8}$$

Instrument k:

$$\frac{\partial m_d}{\partial k} = \frac{Z^d_{m_i} AC'_d \frac{\partial a_d}{\partial m_i}}{\det} = \underbrace{\frac{AC'_d \frac{\partial a_d}{\partial m_i} p' D_d}{\det m_i}}_{>0} \left[\underbrace{\varepsilon_{p',m_i}}_{<0} + \underbrace{\varepsilon_{D_d,m_i}}_{>0} \right]. \tag{A.9}$$

Thus, we have $\frac{\partial m_d}{\partial k} < 0$ for $|\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}|$. Summary of results:

$$\frac{\partial m_d}{\partial \cdot} = \begin{cases} > 0, \text{ for } |\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}| \\ \text{no unambiguous sign} \\ > 0 \\ < 0, \text{ for } |\varepsilon_{p',m_i}| > |\varepsilon_{D_d,m_i}| \end{cases} \quad \text{for} \quad \begin{matrix} f \\ g \\ h \\ k \end{matrix} \tag{A.10}$$

q.e.d.

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