Constrained altruism: agency problems in adaptation financing*

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Abstract

Economic impacts caused by weather related extreme events and gradual climate change will hurt developing country economies the most. International financial transfers are increasingly being sought as crucial to help developing countries adapt. In this paper we use contract theory to investigate what factors affect the feasibility of a financing mechanism to deliver adaptation finance at scale while providing an incentive for adaptation to take place at the lowest possible cost. In particular we look at a representative donor's behavior when different assumptions are made with respect to the observability of adaptation effort by the recipient and with respect to the terms of the financing agreement. If faced with asymmetric information and a constraint that adaptation finance should be provided only through grants or highly concessional loans, the donor may not fund the program. If it does, the expected value of the financial transfer is higher than the incremental cost of adaptation undertaken by the recipient.

1 Introduction

Developing countries will bear most of the costs of the damage from climate change. Many people in developing countries live in physically exposed locations and economically precarious conditions, and their financial and institutional capacity to adapt is limited (World Bank, 2010). International cooperation to support developing countries in addressing the impacts of climate change is crucial to keep development objective targets in sight. As adaptation financing becomes more and more important in the development agenda, it makes sense to understand what its the best way to administer it. For the purpose of managing adaptation finance, we envisage two key requirements: a good understanding of the factors at play, and a sense of how sensitive the relevant stakeholders will be to the concrete initiatives taken.

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In this paper we are interested in investigating what factors affect the feasibility of a financing mechanism to deliver adaptation finance at scale while providing an incentive for adaptation to take place at the lowest possible cost. In particular we look at representative donor's willingness to provide adaptation finance. We check how the donor's decision changes when different assumptions are made with respect to the observability of adaptation effort on the ground and with respect to the terms of the financing agreement. The analytic tool used is the one offered by the theory of contracts, or principal-agent framework. Contract theory is used to analyze the strategic interaction of two economic agents, in our case a donor and a recipient country, whose payoff functions are not perfectly aligned. The principal delegates the realization of a task to the agent, in our case incremental adaptation effort, against the payment of a remuneration that is meant to compensate the agent for the additional cost it bears, and to provide an incentive for good performance.

The novelty of the paper is two fold. The incipient literature on adaptation financing has so far ignored agency problems. We argue that asymmetric information is likely to be pervasive in climate financing and may lead to highly inefficient outcomes. This may in turn explain the deficit of international financial resources available for adaptation. Moreover, the debate on adaptation has mostly focused on how to raise funds while very little analysis has been devoted to the issue of how money should be allocated (Fankhauser & Burton, 2011), and what drives donor's decision to provide adaptation money.

The focus of this paper is on large scale transfers akin to budget support operations, rather than project level financing. In particular, it explores the feasibility of performance-based financing. Existing funds have different methods for allocating resources, ranging from eligibility criteria (e.g. being a Low Income Country Under Stress), the potential for the recipient to contribute to a global public good (e.g. the GEF's STAR system), past performance on economic and social management, governance and implementation of projects (e.g. IDA's CPIA system). Some funds operate on a first-come-first-served basis (such as for example the Climate Investment Funds). Performance-based allocations for large scale financing is being increasingly explored by donors[1] but it is yet to be piloted through large-scale public funds (UNFCCC, 2011).

We start in section 2 discussing the role of the public sector and international donors in financing adaptation to climate change in developing countries. Section 3 motivates our use of contract theory to analyze issues related to adaptation financing. From an economic point of view, the provision of finance is a separate issue from the provision of an incentive for good performance. The principal-agent framework can shed light on the latter. Section 4 develops the model by first assuming perfectly monitorable adaptation effort and then by considering the case in which adaptation effort is not verifiable by the donor. Section 5 discusses the key conclusions.

[1] Currently, REDD+ is experimenting with results-based finance. For example, the Guyana REDD+ Investment Fund (GRIF) allows donors to provide annual contributions that depend in part on the recipient country meeting performance criteria that have been established and verified by the donor (UNFCCC, 2011).

2 The rationale for adaptation financing

Article 4.4 of the United Nations Framework Convention on Climate Change (UNFCCC), adopted in 1992, states that: "[t]he developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects." In this section we discuss the economic arguments for public sector involvement in adaptation and whether the international community can play a role.

2.1 Public sector role in adaptation financing

Developing countries will suffer the most from climate change damages as they are located in geographic areas more exposed to changing weather patterns (Parry et al., 2010), their economies depend on sectors more vulnerable to weather variability, and their social and economic systems are less able to withstand shocks. For these reasons, adaptation is increasingly becoming an important area of investment in developing countries.

Most adaptation actions can be undertaken at the household, firm or community level and will produce benefits (defined as the present value of avoided damages from climate change) directly to those undertaking the actions, hence constituting a private good. In some instances, however, public interventions may be necessary (Lecocq & Shalizi, 2007).

When adaptation is a pure private good, budget constraints may prevent adaptive action by agents and the public sector may provide resources to relax such constraints. In occasions, the agent is not well informed about the risks it faces and the public sector may provide either the means to perform adaptation (as in the case of compulsory health insurance) or the information to raise awareness (as in the case of public campaigns on the effects of smoking). Sometimes the agent does not have property rights over the assets exposed to climate change damages and public sector may provide the means to more secure property rights (land tenure reform can then become an adaptive action).

When (ex-ante) adaptation is a privately provided good but ex-post recovery is provided by the public sector, agents may engage in activities that are riskier than would be socially optimal (moral hazard) and this justifies public sector intervention in regulating agent behavior ex-ante.

Ex-ante adaptation can also be a (possibly local) public good. For example, adaptation actions can benefit multiple agents or group of agents (e.g. irrigation infrastructure, early warning system, information systems) and in this case, unless the public sector intervenes, there will be under provision. In addition, climate change may threaten public goods (e.g. roads and bridges) and in this case the public sector may provide infrastructure upgrades to increase resilience to climate change for the same reasons it builds the infrastructure in the first place.

2.2 International adaptation financing

The discussion above highlights some of the motives for public sector involvement in adaptation. After all, most of the benefit of adaptive actions undertaken by a country fall within the national territory. It is then useful to examine the international community's motives to

foster adaptation in developing countries. A number of arguments have been reviewed in the context of development aid (Mosley (1987), Kanbur (2006)). First of all there is a pure altruism argument. Well-being of citizens in the developing world matters to citizens in richer countries and international aid acts as a way to coordinate the philanthropic desire of developed country citizens (Kanbur, 2006). In the case of adaptation, donor altruism may be important to deal with budget constraints by specific governments that make them unable to invest in adaptation actions. In some cases, the donor community may have a commitment to finance ex-post disaster recovery. Adaptation finance may then be needed to deal with moral hazard behavior on the part of the government who may expect international assistance after a disaster. Finally, adaptation may be functional to the protection of gains from development aid. That is, donors may want to finance adaptation for the same reasons it provides development aid in the first place.

In addition, helping developing countries adapt may indirectly imply financial benefits to the donor. Alesina & Dollar (2000) find considerable evidence that the direction of foreign aid is dictated as much by political and strategic considerations, as by the economic needs and policy performance of the recipients. In addition, climate resilience may reduce the risk of displaced populations and thus reduce the need for border protection and security. International aid and adaptation finance may also ensure stable supplies of commodities from an important trading partner. Terms of trade effect are analyzed in Gale (1974), cited in Kanbur (2006). When there are more than two parties, both donor and recipient can be made better off with the development aid transfer, as a consequence of the change in terms of trade. Mosley (1987) notices that when marginal propensity to consume is higher in recipient country then financial transfer from developed countries can make sense for the latter from a purely financial perspective (this is a sort of Keynesian argument to development aid)[2].

The considerations above imply that there may be a mismatch between local and globally optimal adaptation effort. Actions undertaken by a specific country may be well below the level that would be optimal after taking into account other countries values. The principal-agent framework provides an analytic tool to deal with the problem in a formal way.

3 Adaptation financing through the principal-agent framework

"An agency problem emerges when there is both a divergence of interests between those who perform tasks (agents) and those on whose behalf the tasks are performed (principals), and there is asymmetric information between the two parties" (Paul, 2006). There are then two key elements that characterize the principal-agent relationship: (1) divergence of interests; (2) asymmetric information. Below we look at these in the context of adaptation financing.

[2]Along the general lines of aid giving, Kanbur (2006) notices a political economy dimension. A donor may for example be interested in disposing of agricultural surplus to sustain a particular part of the economy. Aid can be thought of as the national coordination of individual giving (a nations being formed by many agents) in which aid is given through general taxation but is then use to the benefit of a particular agent or set of agents. The political economy approach to aid gives rise to theories of why we observe conditionality.

Through the UNFCCC financial mechanisms the international community wishes to foster, along with greenhouse gas emissions mitigation, resilience to climate change in the most vulnerable countries at the lowest possible cost. The objectives of vulnerable countries may however not be aligned with the objectives of the donor. There may be multiple reasons for this. One reason may be impatience, that is, the recipient country values short term growth and poverty reduction much more than long term growth and resilience and hence puts a lower emphasis on achieving resilience at the cost of less growth today. On the other hand, the donor may have a commitment to provide ex-post recovery assistance to the recipient if climate change damages occur. This commitment undermines the recipient country's incentives to perform adaptation. This problem goes under the name of Samaritan's dilemma (Buchanan (1975), Ostrom et al. (2005)). The key point is that adaptation produces both a private benefit (e.g. long lasting growth) and an externality (e.g. less need for potential ex-post recovery funding). Contract theory has been long used to analyze similar problems in different settings including sharecropping in agriculture, regulation of natural monopolies, labor contracts and financial contracts among others.

A question that often arises in a principal-agent context is whether maximizing the principal's objective while minimizing costs can be achieved when the recipient's effort is not observable, and hence, not contractible. Closely related is the question of what institutional set up can make the job easier: "if agency problems pervade the aid relationship, some of these inherent constraints on the performance of aid programs may be mitigated by informed institutional design" (Paul, 2006).

In the model of section 4 we analyze the case in which the agent's effort is unobservable and hence non-contractible. The easiest way to think about non-contractible effort is through a concrete example. Imagine the donor is interested in reducing vulnerability to climate change induced droughts in a country highly dependent on rain-fed agriculture. To achieve this, the principal decides to finance an adaptation project which encompasses investments in irrigation infrastructure and the promotion of drought resistant crops. The success of the project, measured for example as the reduction in damages caused by droughts compared to a given baseline, crucially depends not only on the project being implemented but it also depends on a series of soft interventions such as ensuring water use and land use rights are distributed in a transparent way and enforced, weather forecasting systems are in place, forecast information is adequately shared with farmers, and farmers have access to credit to obtain the drought resistant technology. Ensuring that such enabling factors for adaptation are in place is a way to think about effort.

It is easy to see how the problem applies to contexts other than drought adaptation in agriculture: one could think of similar issues arising when adapting to floods in coastal areas or when coping with glaciers' retreat in high altitude regions. In all cases, information asymmetries between the principal and the agent are likely to play an important role, giving rise to lengthy and unproductive discussions on the mechanisms to administer adaptation finance. In Bangladesh, disagreement between the government on one side and international donors on the other have resulted in the creation of two separate large trust funds to deal with climate change (Hedger,

2011): the Bangladesh Climate Change Trust Fund - BCCTF - funded by the Government, and the Bangladesh Climate Change Resilience Fund - BCCRF - funded by donors. Hedger (2011) notes that the initial allocations under the BCCTF were made and announced before Cancun and that "during the study, the civil society organizations interviewed made substantial criticisms about the process of allocation and its outcomes. There seems to have been evidence of locational bias to vested political interests and some of the projects were more broadly environmental in focus than targeted for climate change". Monitoring whether funds are allocated to activities that have little to do with climate resilience or that duplicate existing interventions is often not easy.

Asymmetric information has been analyzed in the context of development aid over the past two decades. There is now a considerable literature on the use of contract theory to analyze donor-recipient relationships, partly aiming at shedding light on the mixed results of the empirical literature on aid effectiveness. The idea is to "help articulate in a coherent framework the various results from the empirical literature, and enhance our understanding of the issue" (Azam & Laffont, 2003). Among those analyzing aid effectiveness from an empirical point of view are Boone (1996), Burnside & Dollar (2000) and Collier & Dollar (2002).

Early examples of the use of principal-agent model to analyze the issues at play include that of Murshed & Sen (1995), who analyze moral hazard in the context of development aid with non-economic conditionality (i.e. reducing military expenditure). Drazen (2000) provides a review of the literature mostly focusing on applications for macroeconomic policy, evaluating what has been learned.

Svensson (2000) show that aid induces weak fiscal discipline and that increased fiscal difficulties lead to higher inflow of aid. This may be one explanation for the poor results of the vast amount of foreign aid disbursed to the developing world. Svensson (2000) also show that tied aid, or delegation to a donor agency with less aversion to poverty may improve the equilibrium for all parties in the discretionary environment. In a similar vein, Federico (2001) analyze the commitment problem in the application of conditionality. Cordella & Dell'Ariccia (2007) are concerned with the choice between budget support and project specific aid when the aim is to maximize the effectiveness of development programs.

In this paper we analyze aid effectiveness only in part, and we focus mainly on what drives or hampers a donor decision to provide budget support. The model is similar in its set-up to the one presented in Azam & Laffont (2003), who analyze foreign aid as a contract where the North provides finance to the South in return for poverty reduction which is regarded as an international public good. Unlike Azam & Laffont (2003), adaptation effort is modeled here as the key factor determining the probability of the recipient being able to withstand adverse climate condition, as is also done in Besley & Ghatak (2005) in the context of public good provision. Another novelty of our model is that we explicitly consider the use of performance-based financing schemes.

4 The model

A risk neutral agent, or recipient, allocates its budget b_R, plus and any overseas development assistance f, to current consumption, c_R, and to undertake adaptation effort, a:

$$c_R + \frac{ca^2}{2} \leq b_R + f. \tag{4.1}$$

Adaptation effort a is meant to protect the assets exposed to the negative impacts of climate change. In particular, effort is normalized to vary between zero and one to represent the probability that the assets will withstand a climate shock. Assuming the assets at risk are worth V_R, in present value terms, to the recipient and that a climate related disaster is expected to occur with probability ω, the payoff function of the recipient can be expressed as:

$$\begin{aligned} U_R &= \omega\left(c_R + aV_R\right) + \left(1-\omega\right)\left(c_R + V_R\right) \\ &= c_R + \left(1-\omega\right)V_R + a\omega V_R \\ &= c_R + \left(1-\omega\right)V_R + av_R, \end{aligned} \tag{4.2}$$

with $\omega \in (0,1)$, $v_R = \omega V_R$.

A risk neutral donor allocates its budget b_D to current consumption, c_D, and to provide finance to the recipient:

$$c_D + f \leq b_D. \tag{4.3}$$

The donor puts a positive value on the recipient being less vulnerable to climate change. We denote such value as v_D. The payoff function of the donor can be then expressed as:

$$U_D = c_D + av_D. \tag{4.4}$$

A key feature of the model is that through adaptation effort the recipient produces a public good that both the donor and the recipient care about, and is hence worth v_R+v_D. In particular, the donor puts a positive value on the recipient country being less vulnerable to climate change but it cannot achieve the task on its own. The agent is necessary to perform the project and the only way for the donor to increase the provision of the public good is by writing a contract. The valuations v_D and v_R capture the different propensities of the donor and the recipient to build resilience to climate change in the recipient country.

Notice that that the donor could unilaterally perform emissions abatement and in this way reduce the agent's vulnerability to climate change. Alternatively, the donor may have an implicit commitment to help with ex-post recovery if climate change damages occur. However the cost of emissions abatement or ex-post recovery are high enough to justify the principal's preference for (ex-ante) adaptation. Notice also that the donor's inability to sign a self-enforcing international environmental agreement with other donors, owing to free-riding problems, makes adaptation financing a more practical option.

4.1 Autarky

Provided the agent values the assets at risk, and any compensation ex-post is not sufficient to cover the losses that arise as a consequence of a natural disaster, the agent will unilaterally exert a positive level of adaptation. In particular, the agent will maximize its payoff function subject to its budget constraint:

$$\begin{aligned} &\max_{\{a\}} c_R + (1-\omega) V_R + a v_R \\ &s.t. \\ &c_R + \frac{ca^2}{2} \leq b_R. \end{aligned} \tag{4.5}$$

The first order condition is:

$$ca^A = v_R. \tag{4.6}$$

Adaptation will take place in autarky up to the point in which its marginal cost equals its marginal benefit. The solution of this problem will be characterized by:

$$\begin{aligned} a^A &= \frac{v_R}{c}, \\ c_R^A &= b_R - \frac{v_R^2}{2c}, \\ U_R^A &= b_R + (1-\omega) V_R + \frac{v_R^2}{2c}, \\ U_D^A &= b_D + \frac{v_R v_D}{c}. \end{aligned} \tag{4.7}$$

Notice that the public good nature of adaptation implies that the donor also benefits from a positive adaptation effort by the recipient.

4.1.1 Unconditional adaptation finance or compensation

One way the donor can engage the recipient is by providing unconditional finance. As we show below, this resembles closely the autarky case. Political arguments in favor of this solution include those suggesting that developed countries should compensate developing countries for the damages imposed by climate change. In terms of our stylized contract, unconditional finance can be represented by the provision of an amount of finance f^U with no restriction on the agent's behavior. In such setting, the recipient will always accept the finance and the solution will entail a level of adaptation effort that is unchanged relative to the autarky case. The only difference is a transfer of payoff level from the principal to the donor:

$$
\begin{aligned}
a^U &= a^A = \frac{v_R}{c}, \\
c_R^U &= b_R + f^U - \frac{v_R^2}{2c}, \\
U_R^U &= b_R + f^U + (1-\omega) V_R + \frac{v_R^2}{2c}, \\
U_D^U &= b_D - f^U + \frac{v_R v_D}{c}.
\end{aligned} \tag{4.8}
$$

This result, similar to the one in Azam & Laffont (2003), is made more dramatic by the assumption of no wealth effects on the adaptation decision of the recipient. While somehow extreme, this assumption will allow us to study those aspect of the adaptation financing contract that are strictly related to agency problems.

4.2 Conditional adaptation finance (the first best)

As a benchmark, we consider the case where adaptation finance is associated with the agent undertaking a level of adaptation effort that is set by the donor as a condition to the provision of finance. The financing contract is similar to a budget support operation, in which the finance is provided against the realization of an investment, the approval of a policy, or the creation of new institutional capacity to offer just a few examples. We assume that the donor makes a take-it-or-leave-it offer to the recipient. The donor maximizes its payoff function with respect to the financing f and the adaptation effort a, subject to its budget constraint and the recipient's participation constraint [PC]:

$$
\begin{aligned}
& \max_{\{a,f\}} c_D + a v_D \\
& s.t. \\
& c_D + f \leq b_D \\
[PC] \qquad & b_R + (1-\omega) V_R + f - \frac{c a^2}{2} + a v_R \geq U_R^A
\end{aligned} \tag{4.9}
$$

Given that the recipient can always walk away from the contract, the donor must offer a package that gives the recipient a payoff that is at least as large as in autarky. Both inequality constraints will be binding at the optimum. For any given equilibrium level of adaptation, the donor can reduce the transfer up to the point in which the participation constraint binds. For a given level of transfer, the donor can increase private consumption up to the point in which the budget constraint binds. The solution of the problem can be characterized as follows:

$$
\begin{aligned}
a^{FB} &= \frac{v_R + v_D}{c}, \\
f^{FB} &= \frac{v_D^2}{2c}, \\
c_R^{FB} &= b_R - \frac{v_R^2}{2c} - \frac{v_R v_D}{c} \\
&= c_R^A - \frac{v_R v_D}{c}, \\
U_R^{FB} &= U_R^A, \\
U_D^{FB} &= b_D + \frac{v_R v_D}{c} + \frac{v_D^2}{2c} \\
&= U_D^A + \frac{v_D^2}{2c}.
\end{aligned} \tag{4.10}
$$

It is useful to compare the solutions to maximization problems 4.5 and 4.9. We refer to such comparison in proposition 1, which also describes how donor financing compares to the amount spent by the recipient on adaptation. Before doing so we provide the following definition:

Definition. Incremental adaptation cost (IAC) is the increase in the cost of adaptation borne by the recipient relative to the autarky case.

Proposition 1. *Conditional adaptation finance increases the level of adaptation effort undertaken by the recipient and distorts downwards its consumption. Financing is directly related to the donor's valuation and is always less than the incremental cost of adaptation.*

Proof. The first part of the proposition comes directly from the solution to the donor maximization problem. The second part can be proved by evaluating $U_R = b_R + f - \psi(a) + (1-\omega) V_R + a v_R$ at the solution contracts $\left(a^{FB}, f^{FB}\right)$and $\left(a^A, 0\right)$. Taking the difference of the two expressions, and noticing that such difference is equal to zero given that the participation constraint binds, we obtain the equality $f^{FB} = \psi\left(a^{FB}\right) - \psi\left(a^R\right) - \left(a^{FB} - a^A\right) v_R$. Since $a^{FB} - a^A > 0$, $f^{FB} < \psi\left(a^{FB}\right) - \psi\left(a^R\right)$. □

The next step is to analyze the case in which adaptation effort is not perfectly observable.

4.3 Conditional adaptation finance when effort is observed imperfectly

Facing the increased likelihood of extreme events and adapting to progressive climate change will likely require information, institutions that optimize such information, coordination between relevant stakeholders among other things. Many such actions are difficult to monitor, and hence non-contractible. At the same time, the donor cannot make payments dependent on project outcomes, given the long term nature of most climate change events under consideration.

What the donor might do is to condition the payment to project indicators. In what follows we assume that an indicator to track the achievement of milestones in adaptation investments and policies does exist. In particular, we assume that the indicator can take two values of implementation quality: satisfactory and unsatisfactory. The donor will then make payments conditional on the realization of the indicator:

- when adaptation action implementation is deemed unsatisfactory the payment is equal to f_0,
- when adaptation action implementation is deemed satisfactory the payment is equal to $f_0 + f_1$.

In other words, the recipient receives a payment (or pays a fee) f_0 when signing the contract, and receives a reward f_1 if implementation is graded satisfactory. [3]

Further we assume that the probability of the implementation quality indicator taking an acceptable value is equal to the amount of adaptation effort a. Adaptation financing is now conditional on the implementation indicator and its expected value is given by:

$$\begin{aligned} E(f) &= a(f_0 + f_1) + (1-a) f_0 \\ &= f_0 + a f_1. \end{aligned} \tag{4.11}$$

As shown in the last equality of equation 4.11, the financing package is composed of a fixed component, independent of the indicator's outcome, and a variable component which depends on the indicator. Assume that the fixed component is exogenously determined, for example through a UNFCCC negotiation process, to be not less than a given parameter:

$$f_0 \geq f_0^*. \tag{4.12}$$

The donor's problem can be written as:

$$\begin{aligned} & \max_{\{a, f_0, f_1\}} c_D + a v_D \\ & s.t. \\ & c_D + E(f) \leq b_D \\ [PC] \quad & b_R + (1-\omega) V_R + E(f) - \frac{c a^2}{2} + a v_R \geq U_R^A \\ [IC] \quad & a = \arg\max_a b_R + (1-\omega) V_R + E(f) - \frac{c a^2}{2} + a v_R \end{aligned} \tag{4.13}$$

and equations 4.11 and 4.12.

The problem differs from the case of full observability of effort in that (1) payment is now conditional on the realization of the indicator and, (2) effort being not contractible, the recipient can choose the level of adaptation that maximizes its payoff. The problem must then satisfy the incentive compatibility constraint [IC]. This problem is similar to the one of moral hazard with limited liability constraints originally analyzed by Innes (1990). Depending on the value of the parameter f_0^*, either the participation constraint or constraint 4.12 will bind. We analyze the two cases in turn.

[3] Another way to interpret this payment schedule is to say the agent receives financing $f_0 + f_1$ and commits to pay back an amount f_1 in case the indicator suggests unsatisfactory implementation. No repayment is due otherwise.

If the participation constraint binds, the optimal level of adaptation effort, the agent's consumption and payoff and the donor's payoff are identical to the one in the first best case. This solution is implemented by setting the payment schedule as follows:

$$f_0^{SB} = -\frac{v_D^2}{2c} - \frac{v_D v_R}{c}, \tag{4.14}$$

$$f_1^{SB} = v_D. \tag{4.15}$$

Notice in particular that

$$\begin{aligned} E(f) &= f_0 + a f_1 \\ &= \frac{v_D^2}{2c} \\ &= f^{FB}. \end{aligned} \tag{4.16}$$

Expected financing in the case of imperfectly observable effort is identical to the case of contractible effort[4]. This is made possible by imposing a negative fixed fee, as shown in equation 4.14, and by rewarding the recipient when implementation is satisfactory. In other words, the principal can have the agent bear the full risk of the project by charging it a fixed fee to participate in the scheme and offering a bonus in case of project success. This is what we typically observe with output-based aid in which a service provider is responsible to pay the upfront costs of the project and is offered a subsidy upon verification of project results[5].

If the minimum finance condition 4.12 binds, while the participation constraint does not bind, the solution to the problem entails a lower level of adaptation effort, lower payoff for the donor and higher payoff for the recipient. In particular:

$$\begin{aligned} a^{MF} &= \left(\frac{v_R}{c}, \frac{v_R + v_D}{2c}\right), \\ f_1^{MF} &= \left(0, \frac{v_D - v_R}{2}\right), \\ E\left(f^{MF}\right) &= \left(0, \overline{f_0} + \frac{v_D^2 - v_R^2}{4c}\right), \\ U_R^{MF} &= U_R^A + \overline{f_0} + \frac{\left(v_D + v_R\right)^2}{8c}, \\ U_D^{MF} &= b_D - \overline{f_0} + \frac{\left(v_D + v_R\right)^2}{4c}, \\ &= U_D^A - \overline{f_0} + \frac{\left(v_D + v_R\right)^2}{8c}, \end{aligned} \tag{4.17}$$

[4]This is the well-known result of moral hazard models in which both the principal and the agent are both risk neutral. Provided the principal can impose a high enough punishment to the agent when low effort is observed, the optimal solution will be identical to the first best. This result holds even in the case of noisy indicators of performance, or implementation, as shown in Baker (1992).

[5]See www.gpoba.org

where the subscript MF stands for 'minimum finance'. The incentive is now less high-powered than in the case without the limited liability constraint, and optimal effort is lower. Notice that in this case, if the principal values the project less than the agent (i.e. $v_D < v_R$), it will be optimal for the principal not to provide an incentive at all.

A key feature of the solution is that a positive incentive (i.e. $f_1 > 0$) is less likely the higher the agent's valuation for the project. This is because we assumed that the participation constraint is not binding. When this happens, the principal is giving the agent a costly (for the principal) rent. Such 'limited liability' rent is higher the higher v_R.

We can then state the following proposition:

Proposition 2. *With imperfect monitoring of adaptation effort:*

(a) adaptation financing can produce the first best level of adaptation at no extra cost for the donor and the recipient provided the donor can punish the recipient if monitoring shows unsatisfactory results.

When a lower bound is imposed on the fixed portion of the payment schedule:

(b) $v_D > v_R$ *is necessary for financing to take place;*

(c) there exist a range of values for the fixed portion of the payment schedule, f_0*, such that* $v_D > v_R$ *is also sufficient for financing to take place, and such range includes non-negative values of* f_0*;*

(d) positive values of f_0 *involve* $E\left(f^{MF}\right) > IAC$.

Proof. Part (a) follows directly from solving the maximization problem 4.13. Part (b) follows directly from solving the solution to 4.13 and from noticing that $f_1 = 0$ implies $f_0 = 0$, that is, if the donor does not find it optimal to offer an incentive payment, the fixed portion ceases to make sense as it would simply entail a transfer of payoff from donor to recipient. To prove part (c) we first estimate the value $\underline{f_0}$ above which the participation constraint becomes slack. Note that for $f_0 = \underline{f_0}$ the condition $v_D > v_R$ becomes necessary for the existence of financing. Then we estimate the value $\overline{f_0}$ below which the donor is willing to participate. Finally we check ether $\underline{f_0} > \overline{f_0}$. To estimate $\underline{f_0}$, we substitute a^{MF} and f_1^{MF} in the participation constraint and isolate f_0 to find that $f_0 \geq -\frac{v_D^2+2v_Dv_R-3v_R^2}{8c}$. To estimate $\overline{f_0}$, we notice that for the donor to be willing to provide finance, the following condition must hold: $U_D^{MF} \leq U_D^A$. Substituting a^{MF} and f_1^{MF} in the inequality we find that $f_0 \leq \frac{(v_D-v_R)^2}{4c}$. It is straightforward to verify that $\underline{f_0} > \overline{f_0}$. The estimation of $\overline{f_0}$ also shows that $\overline{f_0} > 0$ provided $v_D > v_R$. This completes the proof of part (c). To prove part (d), substitute $f_0 = 0$ into the expression for $E\left(f^{MF}\right)$ and notice that this value is higher than the value of the incremental adaptation cost $\psi\left(a^{MF}\right) - \psi\left(a^A\right)$. Since $\frac{\partial E\left(f^{MF}\right)}{\partial f_0} > 0$, any positive value of f_0 entails $E\left(f^{MF}\right) > IAC$. □

Proposition 2 provides a mix of good and bad news. As soon as one imposes restrictions on the punishment the donor can apply for bad performance, we walk away from the first best solution. A number of implications follow. If the donor is not altruistic enough, i.e. if $v_D \leq v_R$, no financing will take place. Even if the donor is sufficiently altruistic, i.e. $v_D > v_R$, for financing to take place the fixed portion of the payment schedule must be set at a level that should be lower than a certain threshold. The good news is that such threshold is positive. In

other words, financing can take place through a pair $F = (f_0, f_0 + f_1) = \left(0, f_1^{MF}\right)$, i.e. such that no participation fee is being asked to the recipient. However, the not so good news is that non-negative values of f_0 involve imperfect targeting of resources. That is, part of the financing is going to finance recipient activities that do not entail adaptation.

As a result, in the second best the donor provides less finance but it receives in exchange even less of the public good. Suppose f_0 is equal to its upper bound threshold for donor participation. In this case financing goes down by a fraction $\frac{v_R}{v_D}$ of the first best level, while adaptation effort goes down by half, as seen in solution 4.17.

4.4 Extension: Adaptation and Development

The model presented above is general enough to be applied to describe donor behavior under a wide range of adaptation investment opportunities. In particular, the model could be used to predict donor behavior when financing traditional development programs (e.g. reform of the energy sector, investments in education, conservation of biodiversity hotspots). What is specific to adaptation financing in the model of section 4.3 is the donor's inability to observe the project's outcome. While development finance could in principle be linked to the recipient government achieving certain outcomes (e.g. increases in energy efficiency, education attainment, number of species under threat of extinction), the same is not possible for adaptation finance owing to the fact that resilience to climate change (the desired outcome of an adaptation project) can only be measured after the climate has actually changed. The time scale is arguably much larger. The model in section 4.3 deals with this problem by assuming there is an input indicator that is linked to adaptation effort and that can be used to provide an incentive in the financing package.

As a further issue, it is interesting to consider whether the model predictions change when one incorporates the fact that adaptation produces development co-benefits. So far we have treated adaptation as something the recipient can do to produce resilience to climate change, which is in turn a public good. In reality, adaptation can be a much fuzzier concept. In particular, the boundary between adaptation and traditional development is very difficult to define. McGray et al. (2007) review examples of adaptation efforts drawn from throughout the developing world and note that, from a methodological point of view, there is a significant area of overlap between adaptation and development. "Rarely do adaptation efforts entail activities not found in the development "toolbox." The uniquely "adaptive" elements of most efforts are those involved in defining problems, selecting strategies, and setting priorities—not in implementing solutions." (p. 1).

The implications of this state of affair for donor's willingness to provide finance can be analyzed modifying the model above. In particular, consider the maximization problem in section 4.3. We modify the problem to allow for the fact that adaptation produces development co-benefits (e.g. higher returns on agricultural land during years with good weather) along with resilience to climate change. To do this we modify the recipient's payoff function and budget constraint:

$$\begin{aligned} U_R &= c_R + (1-\omega) V_R + a v_R, \\ c_R + \frac{ca^2}{2} &\leq b_{RN} + b_{RC}(1+a) + E(f), \end{aligned}$$

with b_{RN} representing the portion of the recipient's budget that does not depend on adaptation/development effort and with b_{RC} being the portion of the budget that varies with adaptation/development effort. The higher the level of adaptation/development, the higher the revenues the recipient has available to finance consumption and/or effort in adaptation/development. Assume for simplicity that the recipient puts a zero value on resilience, i.e. $v_R = 0$. The maximization problem of the donor becomes:

$$\begin{aligned} & \max_{\{a, f_0, f_1\}} c_D + a v_D \\ & s.t. \\ & c_D + E(f) \leq b_D \\ [PC] \quad & b_{RN} + b_{RC} + (1-\omega) V_R + E(f) - \frac{ca^2}{2} + a b_{RC} \geq U_R^A \\ [IC] \quad & a = \arg\max_a b_{RN} + b_{RC} + (1-\omega) V_R + E(f) - \frac{ca^2}{2} + a b_{RC} \end{aligned} \tag{4.18}$$

and equations 4.11 and 4.12. The problem 4.18 is identical to the problem 4.13 in all aspects other than the fact that the participation and incentive compatibility constraints now include the revenue benefit of adaptation/development instead of the resilience benefit. The prediction of the model is unchanged, while its interpretation is summarized in proposition 3.

Proposition 3. *With development co-benefits of adaptation, imperfect monitoring of adaptation/development effort and a binding minimum financing constraint, the donor provides adaptation/development finance only if the value of climate resilience to the donor is higher than the private development benefit of the recipient, that is,* $v_D \geq b_{RC}$.

Proof. This result comes directly from solving problem 4.18. □

Knowing the recipient's private benefits of an adaptation/development project is key in determining the donor's propensity to provide finance. McGray et al. (2007) note that the confusion about the relationship between adaptation and development has meant that funding mechanisms may create redundancies or leave gaps in the landscape of critical adaptation and development activities. Our model provides a theoretical understanding of why such gaps might appear.

5 Discussion and conclusions

The theory of contracts provide a useful tool to analyze the relationship between donor and recipient in the provision of development aid. In this paper we have applied the theory to the

problem of a donor wishing to induce an increase in adaptation effort in a recipient country exposed to climate change impacts. We modeled adaptation as the key factor in the production of an international public good, namely resilience to climate change and extreme events. Adaptation can be produced only by the recipient while the donor can provide finance to ensure the incremental cost of adaptation does not imply a lower payoff to the recipient.

We analyzed two key settings: one in which adaptation effort is observable - and hence contractible upon - by the donor, and one in which adaptation can be monitored only partially through the use of input indicators. When effort is fully observable, the donor can make the financing contract conditional on an agreed optimal level of adaptation effort. We showed that conditional adaptation financing increases the provision of the public good relative to the autarky case and relative to the unconditional financing case.

When effort is non-contractible, the donor can condition the payment on the realization of a monitoring indicator. We have assumed the monitoring technology to be given, that is, it is not a variable the donor can modify within the time frame of the model. To analyze this situation we have assumed a payment schedule composed of two transfer levels. A low transfer level paid when the monitoring indicator is unsatisfactory and a high transfer when the indicator is satisfactory. We have reached a number of key insights for adaptation financing.

The existence of moral hazard does not per se cause an inefficient level of adaptation effort on the part of the agent. This holds as long as the principal and the agent are not risk averse. If one includes risk-aversion, the principal faces a trade-off between the benefit of providing incentives and the benefit of insuring the risk-averse agent. A key aspect of the solution is that the low payment is always negative, while the high payment is always positive, and the expected payment is equal to the one made in the case with perfectly observable effort. We noticed that the indicator can be noisy and it may signal project implementation quality with an error. But even in such case the model leads to an efficient effort level. Principal and agent's surpluses will be unaffected.

Including a constraint on the potential fee paid by the recipient when project implementation is unsatisfactory substantially changes the model predictions[6]. This happens as adaptation money is provided through grants or concessional loans. When this is the case, the payment scheme substantially lowers the power of the performance-based incentive. If the donor is not altruistic enough, the financing scheme collapses altogether. If the donor values adaptation highly enough, financing does take place, but the weak incentive induces an adaptation effort level that is half the one in the first best. While the expected payment is also lower than in the first best, it achieves relatively less adaptation. That is, part of the adaptation money ends up as rent to the recipient country. We also found that an equilibrium is possible even when the agreed transfer in case of unsatisfactory performance is positive.

Considering the development co-benefits of adaptation, owing to the fact that adaptation and development are closely related from a methodological point of view does not change the model's predictions qualitatively. But the presence of (private) development co-benefits can make it harder for the donor to be willing to make adaptation finance available on a grant basis.

[6] This constraint has an effect similar to the limited liability constraint discussed by Innes (1990).

The result in this paper provides relevant insights for the establishment of an international regime for adaptation finance. One of the key design issues of the Green Climate Fund is whether finance should take place only through grants or concessional loans. We showed that it is possible for a grant mechanism to still provide incentive for compliance even when effort is not perfectly observable. The trade off, however, is how to balance the need to provide finance at 'fair' conditions while maximizing the impact of scarce adaptation funds.

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