NOTA DI LAVORO

89.2012

North / South Contractual Design through the REDD+ Scheme

By **Mireille Chiroleu-Assouline,** Paris School of Economics (PSE) - Université Paris 1 Panthéon-Sorbonne, Centre d'Economie de la Sorbonne

Jean-Christophe Poudou, Université Montpellier 1, UMR5474 LAMETA

Sébastien Roussel, Université Montpellier 3 Paul Valéry & Université Montpellier 1, UMR5474 LAMETA

Climate Change and Sustainable Development Series
Editor: Carlo Carraro

North / South Contractual Design through the REDD+ Scheme

By Mireille Chiroleu-Assouline, Paris School of Economics (PSE) - Université Paris 1 Panthéon-Sorbonne, Centre d'Economie de la Sorbonne
Jean-Christophe Poudou, Université Montpellier 1, UMR5474 LAMETA
Sébastien Roussel, Université Montpellier 3 Paul Valéry & Université Montpellier 1, UMR5474 LAMETA

Summary

In this paper we aim at theoretically grounding the Reducing Emissions from Deforestation and Forest Degradation + (REDD+) scheme as a contractual relationship between countries in the light of the theory of incentives. Considering incomplete information about reference levels of deforestation as well as exogenous implementation and transaction costs, we compare two types of contracts: a deforestation performance-based contract and a conditional avoided deforestation-based contract. Because of the implementation and transaction costs, each kind of REDD+ contract implies a dramatically different information rent/efficiency trade-off. If the contract is performance-based (resp. conditionality-based), information rents are awarded to countries with the ex ante lowest (resp. highest) deforestation. In a simple quadratic setting, there is a reference level threshold in terms of efficiency towards less deforestation. In terms of expected welfare, conditional avoided deforestation-based schemes are preferred.

Keywords: Conditionality, Contract, Deforestation, Hidden Information, Incentives, Performance, Reducing Emissions from Deforestation and Forest Degradation + (REDD+)

JEL Classification: D82, O13, Q23, Q54

The authors would like to thank conference, workshop and seminar participants for their useful comments over 2012, at the 19th Annual EAERE Conference (Prague), the 61rst Annual AFSE Congress (Paris), the 22nd Annual CREE Conference (Vancouver), the Environmental Economics Meeting -CRESE (Besançon) Workshop, the LAMETA-PERENE Seminar (Montpellier) as well as the TSE-LERNA (Toulouse) Seminar. The usual disclaimers apply.

Address for correspondence:

Mireille Chiroleu-Assouline
Paris School of Economics (PSE)
Université Paris 1 Panthéon-Sorbonne
Centre d'Economie de la Sorbonne
106-112 Bd de l'Hôpital
75647 Paris Cedex 13
France
Phone: +33 1 44 07 82 2
E-mail:Mireille.Chiroleu-Assouline@univ-paris1.fr

The opinions expressed in this paper do not necessarily reflect the position of
Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano (I), web site: www.feem.it, e-mail: working.papers@feem.it

North / South Contractual Design through the REDD+ Scheme

Mireille Chiroleu-Assouline* Jean-Christophe Poudou†

Sébastien Roussel‡§

First version: January 30, 2012

This version: September 29, 2012

Abstract

In this paper we aim at theoretically grounding the Reducing Emissions from Deforestation and Forest Degradation + (REDD+) scheme as a contractual relationship between countries in the light of the theory of incentives. Considering incomplete information about reference levels of deforestation as well as exogenous implementation and transaction costs, we compare two types of contracts: a deforestation performance-based contract and a conditional avoided deforestation-based contract. Because of the implementation and transaction costs, each kind of REDD+ contract implies a dramat-

*Paris School of Economics (PSE) - Université Paris 1 Panthéon-Sorbonne, Centre d'Economie de la Sorbonne, 106-112 Bd de l'Hôpital, 75647 Paris Cedex 13, France, *Tel:* +33 1 44 07 82 24, *E-mail:* Mireille.Chiroleu-Assouline@univ-paris1.fr

†Université Montpellier 1, UMR5474 LAMETA, F-34000 Montpellier, France. *Tel:* +33 4 34 43 25 06. *E-mail:* jean-christophe.poudou@univ-montp1.fr

‡Université Montpellier 3 Paul Valéry & Université Montpellier 1, UMR5474 LAMETA, F-34000 Montpellier, France. *Tel:* +33 4 34 43 25 49. *E-mail:* roussel@lameta.univ-montp1.fr

§Acknowledgements. The authors would like to thank conference, workshop and seminar participants for their useful comments over 2012, at the 19th Annual EAERE Conference (Prague), the 61rst Annual AFSE Congress (Paris), the 22nd Annual CREE Conference (Vancouver), the Environmental Economics Meeting - CRESE (Besançon) Workshop, the LAMETA-PERENE Seminar (Montpellier) as well as the TSE-LERNA (Toulouse) Seminar. The usual disclaimers apply.

ically different information rent / efficiency trade-off. If the contract is performance-based (resp. conditionality-based), information rents are awarded to countries with the *ex ante* lowest (resp. highest) deforestation. In a simple quadratic setting, there is a reference level threshold in terms of efficiency towards less deforestation. In terms of expected welfare, conditional avoided deforestation-based schemes are preferred.

JEL classification: D82, O13, Q23, Q54.

Keywords: Conditionality, Contract, Deforestation, Hidden Information, Incentives, Performance, Reducing Emissions from Deforestation and Forest Degradation + (REDD+).

1 Introduction

Climate change is a worldwide issue that needs to be tackled regarding human-induced activities and pressure on natural resources. One of the primary sources of carbon emissions is deforestation and forest degradation, which are responsible for anthropogenic GHG emissions of about 12% (Van der Werf *et al.* (2009)) to 15-20% (IPCC (2007a, 2007b)). These emissions are the second highest human-induced source of climate change (Lederer (2011)). More specifically, tropical forest deforestation through land-use change was responsible for about 25% of all carbon emissions in the 1990s (Heal and Conrad (2006)).[1] There is an urgent need to cope with deforestation as induced climate change costs are estimated to increase to USD 1 Trillion by the 2100 time horizon (Eliasch (2008), cited by Lederer (2011)). Curbing deforestation is not an infeasible task (Kindermann *et al.* (2008)). Eliasch (2008) states that 3.5 Gt CO2 could be saved per year. As a consequence, there is a need to design suitable international institutional arrangements.

To deal with the deforestation and forest degradation issue, the international community has been promoting the Reducing Emissions from Deforestation and Forest Degradation + (REDD+) scheme to shape the post-Kyoto architecture.[2] The REDD+ scheme was first

[1] This figure is similar to fossil fuel emissions in the US economy, responsible for 27% of all carbon emissions.

[2] Hereafter we refer equally to REDD and REDD+, whereas REDD is the original scheme and REDD+ stands for its latest progress including biodiversity or soil erosion. Nevertheless, in this paper we focus our analysis on deforestation.

launched in Bali in 2007 at the 13th Conference Of the Parties (COP13) to the United Nations Framework Convention on Climate Change (UNFCCC) (proposal from Costa-Rica and Papua New Guinea), and was consecrated at the COP16 in Cancun in 2010 and at the COP17 in Durban in December 2011. REDD+ stands as a multi-lateral agreement at the international level. This scheme will take place in three sequential phases (Zarin *et al.* (2009); Delacote and Simonet (2012)): a readiness phase mainly financed through international funds such as the Forest Carbon Partnership Facility (FCPF) of the World Bank, the UN-REDD Programme, in order to assess state-of-the-art carbon stocks and deforestation levels (Phase 1); an implementation phase based on developing countries' national policies and means (Phase 2); a compensation phase towards the developing countries based on performance achieved in reducing deforestation (Phase 3). The funding countries could choose either to finance successively both the implementation and compensation phases or to fund exclusively one of these phases.

Regarding the relationships between developed and developing countries, the idea of the REDD+ scheme is rather simple and intuitive: developed countries (or Northern countries) pay developing countries (or Southern countries) to implement reductions in carbon emissions from forests, whilst covering their opportunity costs to do so in altering their development paths. This payment occurs either by a direct monetary transfer (through a bilateral relationship or a global fund), or through carbon offsets or credits saleable on the carbon market. The payment-basis lies in per unit reductions of deforestation in comparison to a baseline that needs to be agreed upon (this means the Business-As-Usual (BAU) deforestation level if the REDD+ scheme were not effective or rather the Reference Level (RL), or crediting baseline, which allows compensation to the developing country if emissions are below that level within the REDD+ scheme[3]). Developed countries benefit from climate change mitigation in avoiding taking any action to cope with carbon emissions directly. They delegate the climate change mitigation task to developing countries by rewarding them.

There is an ongoing debate with regards to the REDD+ scheme in terms of rewards given to developing countries. According to Karsenty and Ongolo (2012), the originality of REDD

[3]Hereafter we refer to Reference Level (RL) in favouring the REDD+ requirements.

lies in its incentive properties since intrinsically it rewards States for their achievements in actions against deforestation. They stress that REDD payments are therefore basically performance-based (through the third phase described above) and this leaves the choice of policy instruments to the recipient countries. As a consequence, REDD payments are not related to the adoption of policy measures or changes in the legal or institutional framework (through the implementation phase described above). In other words, there is no conditionality and REDD is "*not encroaching on the sovereign discretion of nations to design acceptable and adequate policies and measures nationally*" (Streck (2010) cited by Karsenty and Ongolo (2012)).

In the literature, several studies have been interested in climate change mitigation and low cost policies compared to costly abatement of fossil fuel emissions, in particular regarding *avoided deforestation* (Heal and Conrad (2006), Murray *et al.* (2009), Figuières *et al.* (2012)). Linking deforestation and REDD, Combes-Motel *et al.* (2009) sum up the existing proposals regarding avoided deforestation, and propose to relate avoided deforestation to effective domestic efforts in developing countries (NGO actions, etc.), and to compensate these efforts. One of our aims is to assess the effectiveness and efficiency of this proposal. According to Figuières and Midler (2011), the REDD proposal looks like a cost-effectiveness tool, and the underlying question is how to impose an exogenous limit or any limit on deforestation at the lowest cost for financing countries. Deforestation is a negative externality that can be internalized through a modified version of "compensation mechanisms" (Varian (1994)), and they design fair rules towards REDD. For our part, we distinguish our approach whilst using the theory of incentives whereas this limitation is embodied in the contract.

The REDD scheme implementation has been considered by Leplay *et al.* (2011) through: on the one hand, a bilateral relationship between a developed country and a developing country; and on the other hand, Payments for Environmental Services (PES) from a developing country to local communities. But they do not consider any incomplete information issue in both stages. Karsenty and Ongolo (2012) describe literally how the theory of incentives is at the core of the REDD+ scheme, and they request conditionalities for carbon payments.

Moreover, some authors and NGOs argue that the methodology currently used to assess

the RL of deforestation rates for the developing countries during the first phase usually overestimates them (Angelsen (2008), Gregersen *et al.* (2010), Ekins *et al.* (2011)) because it relies only on the marginal opportunity cost of forest preservation and neglects transaction, implementation and governance costs. Actually, a couple of bilateral contracts have already been signed that appear to suffer from this kind of discrepancy between high *ex ante* reference levels of deforestation and surprisingly low actual deforestation rates leading to significant avoided deforestation and accordingly to large money transfers between the donor country and the developing country (*e.g.*, Norway *versus* Guyana or Indonesia).

The first objective of our article is to theoretically ground the REDD+ scheme as a contractual relationship between countries in the light of the theory of incentives (Laffont and Tirole (1993), Laffont and Martimort (2002)). To our best knowledge, there is no analytical paper of the REDD+ scheme in terms of the theory of incentives with a Principal-Agent relationship with incomplete information and exogenous implementation and transaction costs.[4] We aim at revealing what is at stake in designing these contracts.

The second objective is to show that two types of contracts are feasible: on the one hand, a performance-based contract corresponding to the current way to consider avoided deforestation; on the other hand, a conditionality-based avoided deforestation contract corresponding to proposals arising in the literature and policy papers.[5] The conditional approach can be designed through observable actions or effective efforts towards avoided deforestation. Both contracts are incentive feasible and ground the REDD+ scheme in a different manner: the performance-based contract corresponds to the compensation phase of the REDD+ funding, whereas the conditional avoided deforestation-based contract grounds the implementation phase of the REDD+ funding. Asymmetric information indeed prevents policymakers from using first-best economic instruments through information rents with trade-offs between efficiency and information rents.

[4]Chiroleu-Assouline and Roussel (2010) already used these theoretical tools to design incentive mechanisms promoting soil carbon sequestration.

[5]These two contractual relationships are connected to input or output incentive schemes formerly analyzed by Crampes (1983) and Maslin and Riley (1985). These papers point out the superiority of output based schemes in asymmetric informational contexts.

The third objective is to discuss what are the menu of contracts a developed country should offer in terms of environmental efficiency regarding a developing country's hidden information and expected welfare. The underlying question within our methodological approach is the following one: how does incomplete information increase the costs of the REDD+ scheme through information rents for each kind of contract?

In our analytical framework, we obtain several important results. Firstly, we can state that, because we take account of implementation and transaction costs, each kind of REDD+ contract implies a different information rent / efficiency trade-off. If the contract is performance-based, information rents are awarded to countries with the *ex ante* lowest deforestation in order to encourage them to induce the highest efficiency whilst coping with deforestation. A puzzling consequence emerges: the resulting avoided deforestation through effective domestic efforts can be decreasing with the baseline announced. If the contract is conditionality-based, then this does play in the opposite way as information rents are awarded to countries with the *ex ante* highest deforestation, and therefore the optimal scheme implies tackling forest areas where deforestation is *per se* the highest. Secondly, whilst comparing these contracts, there is a baseline threshold in terms of environmental effectiveness concerning less deforestation.

The remainder of this paper is organised as follows. In Section 2, we develop a bare-bones example to outline as simply as possible the economics of our analytical arguments and results. In Section 3, we present our theoretical Principal-Agent model. In Section 4, we design and analyse the performance-based contract that we call the deforestation performance *(DP)* scheme, whereas in Section 5, we design and analyse the conditionality-based effective domestic efforts contract that we call conditional avoided deforestation *(CAD)* scheme. A full discussion is provided in Section 6 in terms of contract comparisons regarding their efficiency towards lower deforestation, baseline assessment and political economy insights. Section 7 concludes.

2 Private information and disclosure within a contract: a bare-bones example

In this section, we compute a simple bare-bones numerical example illustrating the intuitions behind and the economics of the REDD+ contracting schemes that we will consider. For the sake of simplicity, we reason in terms of the deforestation rate, the baseline rate and the Reference Level (RL) within a developing country, as well as in USD millions regarding respectively the benefits of deforestation, the costs of avoiding deforestation, and monetary compensation from Northern countries to Southern countries.

The Baseline, Reference Level and monetary compensation

Consider a developing country (say Indonesia or Guyana) which knows exactly what deforestation rate it would expect to achieve per year as a baseline, *e.g.*, 0.25% per year. We suppose that this country specifies its baseline through reports of private experts it has hired as consultants. Consider a developed country as a donor (say Norway) that does not know exactly what the rational base for computing this baseline is. This donor country thinks that this baseline is 0.25% with a probability of 1/2 but 0.36% with a probability of 1/2. Obviously reducing deforestation implies a costly effort (greater than the sole opportunity cost of loosing the utility derived from deforestation, because of transaction and implementation costs) for the developing country which must be compensated. Hence the donor country will propose a menu of contracts and expect that announcing a high baseline will yield to initiatives by the developing country that will strongly moderate its deforestation. In turns, the donor country will anticipate that larger costs will have to be reimbursed and so the monetary transfer will increase with the RL that is set. Assume for simplicity that the developing country's net benefit is exactly the effective deforestation level achieved minus the cost to avoid deforestation which differs with regards to the baseline rate. For example, if the effective deforestation rate was 0.09% for a developing country whose RL is 0.25%, then the domestic effort to reduce deforestation is -0.16% and costs USD 80M.[6] Assuming

[6]It is presumed that the cost of avoiding deforestation (in USDM) is $c(RL, D) = \frac{(RL-D).10^4}{2}.10$ with RL

RL (%)	D (%)	AD (%)	T (MUSD)		RL benefits (MUSD)	Contract benefits (MUSD)
0.25	0.09	0.16	160	....	200	200
0.36	0.16	0.20	180		240	240

Table 1: Informed contractual proposal

that in a developing country, the gross benefits are based on the deforestation rate achieved, for example USD 120M in this case for a 0.09% rate,[7] the developing country's net benefits would be $120 - 80$ =USD 40M if avoided deforestation was effective. Hence, there is a need to compensate the net loss (here USD 80M) through a North / South monetary transfer to support a deforestation reduction by the developing country. This is the aim of the REDD+ mechanism which will involve a transfer to genuinely compensate these kinds of losses.

If there is not any private information about RL rates, it is assumed that the contractual arrangement proposed by the donor would be writen as summarized in Table 1 (with Reference Level (RL) rate, Deforestation (D) rate, Avoided Deforestation (AD) rate and Transfer (T) in USDM, RL benefits in USDM and contract benefits in USDM).

This example features deforestation and avoided deforestation rates that are correlated to the RL rate set. For a developing country whose RL is 0.25% and effective required deforestation is 0.09%, net benefits through compensation are $120 - 80 + 160$ =USD200M which is just equal to the RL benefits outside any contractual arrangement as the REDD+ scheme. RL benefits and contract benefits are respectively USD200M. The same holds for a 0.36% RL and an 0.16% effective deforestation rate at USD240M.

However, as a donor country does not know exactly what the real RL rate is, such a contractual arrangement could be manipulated by a developing country.

Unobservable domestic reduction efforts

Firstly, let us consider that avoided deforestation through domestic reduction efforts is difficult to observe by the donor country implying that only subsequent deforestation is

the Reference Level rate and D the Deforestation rate.

[7]It is presumed that the benefit of any deforestation rate per year is (in USDM) is $u(D) = 40.(D.10^4)^{1/2}$with D the Deforestation rate.

RL (%)	D (%)	AD (%)	T (MUSD)
0.25	0.16	0.09 (0.25 − 0.16)	180
0.36	0.16	0.20	180

RL ben. (MUSD)	"Cheating" ben. (MUSD)
200	295

Table 2: Asymmetric information on the Deforestation level

observed (*ex post*). In negociating with this kind of developing country, the developed country decides to offer a menu of performance-based contracts as $< T, D >$. Then a developing country with an 0.25% RL that currently chooses the contract set for a developing country with an 0.36% RL will earn some rents from its private information. Indeed, having a higher effective deforestation rate of 0.16% required within this contract (in lieu of 0.09%), its gross benefits will be of USD160M though its real applied effort to avoid deforestation will not be of -0.2% but of -0.09% ($0.16\% - 0.25\%$) with 0.25% being its genuine RL which costs only USD45M (unlike the previous cost at USD80M). Hence the so-called rent (benefit) will be of USD95M since the net benefit of "cheating" or "mimicking a higher RL" is $160-45+180$ =USD295M whereas its RL real benefit outside any contractual commitment should be USD200M. Hence the developing country whose real RL is 0.25% has an incentive to overstate its RL rate:[8] this has a detrimental effect on the efficiency of the menu of contracts previously proposed. We sum up this situation in Table 2.

Observable domestic reduction efforts

Secondly, if we consider that domestic efforts to avoid deforestation are observable and contractable for the donor country, then the developed country decides to offer a menu of contracts based on public policy levers as $< T, AD >$. Then a developing country whose RL is 0.36% will choose the contract set for a developing country whose RL is 0.25%. This means that a developing country will choose a contract in which the avoided deforestation rate is lower than what is expected under its suitable commitment and then will earn some rents from its private information. Indeed, having a lower domestic effort to avoid deforestation at-0.16% (in lieu of -0.20%), the cost of avoiding deforestation will be set at USD80M but its real benefit will be of USD179M in deforesting at a higher rate at 0.20% ($0.36\% -$

[8]One can check that the 0.36% rate country does not have such an incentive since its net benefit whilst "mimicking" a lower RL country is USD15 5M lower than the RL reward (USD240M).

RL (%)	D (%)	AD (%)	T (MUSD)
0.25	0.09	0.16	160
0.36	0.20 (0.36 − 0.16)	0.16	160

RL ben. (MUSD)	"Cheating" ben. (MUSD)
240	259

Table 3: Asymmetric information on the Avoided Deforestation level

0.16%) (unlike the previous benefit of USD120M). Hence, the so-called rent (benefit) will be of USD19M since the net benefit of "cheating" this way or "mimicking a lower RL" is $179 - 80 + 160$ =USD259M whereas the RL real benefit outside any contractual commitment should be USD240M. Hence the developing country whose actual RL is 0.36% RL now has an incentive[9] to understate its RL rate. This leads also to a detrimental effect on the contract efficiency.

Facing these uncertainties, how can a donor country manage to design an REDD+ scheme with a recipient country? This is exactly the aim of our analysis, in which any developed country can offer a menu of incentive contracts that leads the developing country to choose the suitable contract and therefore to reveal its private information (*i.e.*, regarding its RL, either its real deforestation rate, or its avoided deforestation rate). We sum up this situation in Table 3

Incentive contract in the case of unobservable domestic reduction efforts: performance-based rewards

We claim that when developing countries domestic efforts to avoid deforestation are unobservable, the donor country could propose such a deforestation performance incentive contract based on required *ex post* deforestation rates displayed in Table 4.

RL (%)	D (%)	AD (%)	T (MUSD)
0.25	0.09	0.16	171.5
0.36	0.195	0.165	62

Inc. cont. ben. (MUSD)	"Cheating" ben. (MUSD)
211.5	211.5

Table 4: Deforestation Performance incentive contract

In this deforestation performance incentive contract, the effective deforestation allowed to any 0.36% RL country is higher than in the initial setting (0.195% in lieu of 0.16%)

[9]Conversely one can check that the 0.25% rate country has no such an incentive, as its net benefit to mimic a higher RL country is lower than the RL outside option reward.

implying that the induced avoided deforestation is lower (0.165% in lieu of 0.2%), whereas the monetary transfers allowed are henceforth respectively USD171.5M for a 0.25% RL country and USD62M for a 0.36% RL country (in lieu of respectively USD160M and USD180M). Note that in this setting, the transfers are higher at 0.25% RL and are then decreasing, compared to the initial situation. In this contract, the developed country pays a so-called information rent to the 0.25% RL country, valued at USD11.5M ($171.5 - 160 =$ USD11.5M). This is an incentive for the developing country to choose its corresponding contract and to behave accordingly. The incentive contract benefits are therefore set to USD211.5M.

Incentive contract in case of observable domestic reduction efforts: rewards for public policy levers

When developing countries' domestic efforts to avoid deforestation are observable, the donor country could propose such a conditional avoided deforestation incentive contract displayed in Table 5.

RL (%)	D (%)	AD (%)	T (MUSD)
0.25	0.10	0.15	149
0.36	0.16	0.20	197

Inc. cont. ben. (MUSD)	"Cheating" ben. (MUSD)
257	257

Table 5: Avoided Deforestation incentive contract

In this conditional avoided deforestation incentive contract, the avoided deforestation required to any 0.25% RL country is lower than in the initial setting (0.15% in lieu of 0.16%) implying an higher induced deforestation (0.1% in lieu of 0.09%), whereas the monetary transfers allowed are henceforth respectively USD149M for a 0.25% RL country and USD197M for a 0.36% RL country (in lieu of respectively USD160M and USD180M). Note that in this setting, the transfers are lower at the 0.25% RL and are then increasing as in the initial situation to obtain a higher level at the 0.36% RL. In this contract, the 0.36% RL country earns USD17M ($197 - 180 =$USD17M) in information rent. This is an incentive for the developing country to choose its corresponding contract and to behave accordingly. The incentive contract benefits are therefore set to USD257M.

This bare-bones numerical example explains exactly the rationale and what has been

currently at stake in the Guyanan "economically-rational" deforestation baseline reporting for example (with unobservable domestic efforts to avoid deforestation). In the Guyanan case, the real RL regarding the annual average deforestation rate over the 2000-2009 period is bound to 0.03% per year while Guyana has obtained a contractual commitment with Norway on a 0.275% per year basis worth USD250M in compensation transfers.[10] The Guyanan real RL has therefore been inflated and Guyana will probably earn some rents from its private information. Indeed, having a higher effective deforestation rate at 0.275%, its gross benefits will be higher, though their real applied efforts will be lower and less costly. Hence there is a net benefit of "mimicking a higher RL" country. This depicts the relevance of our analysis and how we can enlighten possible incentive contract mechanisms within the REDD+ scheme to cope with these issues regarding developing countries' baseline reporting. Furthermore, we extend this framework towards observable avoided deforestation through public policy levers in developing countries.

Theoretically speaking, our previous reasoning states the intuitions as if there were only two types of developing countries that a developed country can make contracts with, and that a choice has to be made depending on the possibility of observing domestic reduction efforts. We extend all these intuitions to a continuum of types in the following sections.

3 The model

There is a bilateral relationship via the REDD+ scheme between a developed country and a developing country, respectively hereafter the Principal denoted as P and the Agent denoted as A. The P is a developed country, *e.g.*, Norway, or a supranational funding institution centralizing contributions by developed countries. A denotes a developing country, *e.g.*, Indonesia or Guyana.

Within this relationship, their objectives can be summed up in the following way:

- The aim of P is to reduce deforestation to mitigate climate change whilst delegating

[10] Guyana did mandate McKinsey & Company to provide reports and economic policy orientation on forest management, as did other developing countries such as Democratic Republic of Congo or Indonesia.

this task to A.

- The aim of A is to stimulate its economic growth whilst controlling deforestation according to a set of thresholds regarding its commitment with P.

Implementing the REDD+ scheme requires designing an institutional arrangement between P and A to reduce the occurrence of incomplete information (private information on A's side) and then inefficiency in forest protection. The REDD+ scheme can be described as follows (along the lines of Karsenty and Ongolo (2012)):

- P would like an overall reduction in deforestation (mainly tropical forests). P proposes an institutional arrangement to A which is *a priori* capable of modifying deforestation levels, but there are also opportunity costs in reducing these levels. The payment from P to cover these costs takes the form of a direct bilateral payment or via an international fund.

- P does not know exactly what are the costs and benefits for A to reduce deforestation. This is the source of incomplete information between parties.

- To create incentives to reduce deforestation, P offers a menu of contracts (take-it or leave-it offer), and if a contract is signed P covers the opportunity cost of A which alters its economic growth and also pays some information rent to A.

Here $\theta \in [\underline{\theta}, \bar{\theta}]$ is a type that represents the intrinsic level of deforestation as a baseline, with $\underline{\theta} > 0$. It is distributed with respect to $F(\theta)$ which is a logconcave common prior,[11] where associated (inverse) hazard rates are denoted $\varphi(\theta) = F(\theta) \diagup f(\theta)$ and $\bar{\varphi}(\theta) = (1 - F(\theta)) \diagup f(\theta)$. Suppose that $\underline{\theta}$ is the least deforesting type, and $\bar{\theta}$ is the most. This informational variable can be viewed as a reduced form of deforestation as a baseline or RL that a given eligible country will privately achieve depending on its economic growth and development, its demographic growth, timber export prices, climatic events, etc. (Combes-Motel *et al.* (2009)). In some sense, this is an exogenously given proxy of the deforestation baseline which can be found in applied REDD+ schemes.

[11] This standard assumption ensures that $\varphi(\theta) = \frac{F(\theta)}{f(\theta)}$ is increasing and $\bar{\varphi}(\theta) = \frac{1-F(\theta)}{f(\theta)}$ is decreasing in θ.

The *ex post* deforestation level d (realized and publicly observed) depends on the country's effective effort in avoiding it ($a \geq 0$) in such a way that $d(\theta, a) = \theta - a$. Hence except for A, it is not possible to distinguish between the contribution of the intrinsic type θ and the effective effort to avoid deforestation a. To separate what is at stake for θ and a, one can use the following classification (Table 6).

Structural or intrinsic variables for any developing country (θ)
Economic growth (business cycle)
Economic development
Demographic growth
Initial forest area
Avoided deforestation through domestic policies and measures (a)
Public policies dedicated to deforestation reduction
Forest conservation (national parks, etc.)
Land tenure
Fight against corruption and illegal loging
Other public policies with potential effects
Road infrastructure
Change in rural employment
Governance and institutions
Agricultural policies
Joint effects of structural factors and domestic policies (θ and a)
Export agricultural commodity prices
Timber export prices
Climatic events
Foreign debt
Real Exchange rate
Trade and financial openess
Technological change

Table 6: Main variables related to deforestation and possible reduction levers (adapted from Combes-Motel *et al.* (2009))

The avoided deforestation a is costly for A which incurs not only the opportunity cost of the "lost" deforestation but also implementation and transaction costs. These costs are

assumed here to be exogenous represented by a monetary disutility $\psi(a)$ (whilst altering the country development path) such that $\psi(0) = 0, \psi'(a) > 0$ and $\psi''(a) \geq 0$.[12] We also assume convexity of the marginal cost of efforts that is $\psi'''(a) \geq 0$.[13] Hence A's gross surplus is $u(d)+t-\psi(a)$, where $u(d)$ is the gross utility of deforestation for A assumed to be increasing and concave,[14] and t the monetary transfer in the REDD+ scheme. However outside the REDD+ scheme efforts are nil,[15] so A's outside option is $u\left(d(\theta)\right) = u\left(\theta\right)$. The developed country P which offers the REDD+ mechanism derives a net surplus $W = w(d)-(1+\lambda)t$ from deforestation, where $w(d)$ is its gross utility assumed to be strictly decreasing and concave,[16] and λ is the marginal cost of public funds for P regarding the monetary transfer t towards A. All agents are risk-neutral.

In the following sections, two types of mechanisms are considered:

- a deforestation performance scheme $< t, d >$: effective domestic efforts to reduce deforestation are unobservable and cannot be contracted upon, with A's gross surplus as $U = u(d(\theta)) + t(\theta) - \psi(\theta - d(\theta))$.

- a conditional avoided deforestation scheme $< t, a >$: effective domestic efforts to avoid deforestation are observable and can be included in the mechanism through conditionality, with A's gross surplus as $V = u(\theta - a(\theta)) + t(\theta) - \psi(a(\theta))$.

As a benchmark and to clarify the issues involved, let us consider what would be the first-best REDD+ mechanism for which information on the RL proxy θ is common knowledge. Effective efforts are observable and both the deforestation performance based and the conditional avoided deforestation based schemes are equivalent. In such a situation, the Principal P can extract costlessly all the A's net surplus (so U or V are set with $u\left(\theta\right)$) and enforce any

[12] These implementation and transaction costs could be in turn endogenized through the theory of incentives at a national level between a government and land-users.

[13] This technical assumption avoids non-convexities in the P's optimization problem when information is asymmetric.

[14] Again we assume that the technical assumption $u'''(d) \geq 0$ holds, in order to avoid non-convexities when information is asymmetric. This means that marginal utility must be convex.

[15] Indeed if $t = 0$ then $-u'(\theta - a) - \psi'(a) < 0$ so that the optimal effective domestic effort $a^* = 0$.

[16] As a developed country obtains utility from less deforestation whilst allowing it for example, to get carbon credits (as with a CDM).

avoided deforestation $a(\theta)$ which yields to a deforestation level $d = \theta - a(\theta)$ that maximizes:[17]

$$\begin{aligned} \max_{a(\theta)} W &= w(\theta - a(\theta)) - (1+\lambda)t(\theta) \\ s.t.\ t(\theta) &\geq u(\theta) + \psi(a(\theta)) - u(\theta - a(\theta)) \end{aligned}$$

As a result, the first best avoided deforestation $a^{FB}(\theta)$ obeys to the marginal condition:

$$w'(\theta - a^{FB}(\theta)) + (1+\lambda)\left(u'(\theta - a^{FB}(\theta)) + \psi'(a^{FB}(\theta)\right) = 0$$

so that the deforestation level states at $d^{FB}(\theta) = \theta - a^{FB}(\theta)$.[18] At the social optimum, avoided deforestation efforts balance the P's marginal cost associated with the deforestation level d, *i.e.*, $w'(d)$, and the A's marginal cost or benefit associated with the deforestation level d involved by the REDD+ scheme (which costs $1+\lambda$ for each dollar transferred), *i.e.*, $(1+\lambda)[u'(d) + \psi'(\theta - d)]$. By supermodularity[19] of W in a and θ (resp. in d and θ) then $a^{FB}(\theta)$ is an increasing function of θ (so is $d^{FB}(\theta)$).[20] Concerning the first best transfer, one can see that it is not certainly increasing (or decreasing) with θ:

$$t'^{FB}(\theta) = a'^{FB}(\theta)\left[\psi'(a^{FB}(\theta)) + u'(d^{FB}(\theta))\right] + u'(\theta) - u'(d^{FB}(\theta))$$

However, this first-best contract is not optimal if θ is private information for A . Indeed for A, reporting to P a baseline $\hat{\theta}$ instead of θ, leads to a net information rent $\mathcal{U}(\theta, \hat{\theta})$ depending on whether the deforestation level $d^{FB}(\theta)$ or the domestic efforts to avoid deforestation $a^{FB}(\theta)$ is really applied by the agent once it has signed the contract.

This leads us to state the following result (proof in Appendix 8.1).

Lemma 1 *The first best REDD+ mechanism tends to be manipulated by developing coun-*

[17] As $U = V = u(\theta)$, then $u(\theta) = u(\theta - a(\theta)) + t(\theta) - \psi(a(\theta)) \Leftrightarrow t(\theta) = u(\theta) - u(\theta - a(\theta)) + \psi(a(\theta))$.

[18] Moreover letting $a = \theta - d$, optimizing over d yields the same result in this first best setting.

[19] By concavity of $w(d)$ and $u(d)$ then $\frac{\partial^2 W}{\partial a \partial \theta} = -\left[w''(\theta - a^{FB}(\theta)) + (1+\lambda)u''(\theta - a)\right] > 0$. Moreover simple comparative statics show that $a^{FB\prime}(\theta) = \frac{w''(\theta - a^{FB}(\theta)) + (1+\lambda)u''(\theta - a^{FB}(\theta))}{w''(\theta - a^{FB}(\theta)) + (1+\lambda)(u''(\theta - a^{FB}(\theta)) - \psi''(a^{FB}(\theta))} \in]0,1[$.

[20] Indeed, when defining W as a function (d, θ), (with $a = \theta - d$), it is also supermodular as $\frac{\partial^2 W}{\partial d \partial \theta} = (1+\lambda)\psi''(\theta - d) > 0$.

tries. If a first best deforestation performance scheme is proposed, they are encouraged to overstate their baseline announcement; however if a first best conditional avoided deforestation scheme is proposed, they are likely to understate their baseline announcement.

Consequently, a second best REDD+ mechanism has to be designed to counterbalance all these caveats. We consider successively those second best settings in the following sections.

4 The deforestation performance scheme

The REDD+ mechanism is built in such a way that when a country A announces a baseline $\hat{\theta}$ then P expects that A must achieve a deforestation level of $d(\hat{\theta})$. The underlying idea is that deforestation reductions are compensated and payments are based on performance.

P offers a menu of contracts to A (take-it-or-leave-it offer) as $< t(\theta), d(\theta) >$ and the timing of the game is summarized in Figure 1.

For a given RL $\hat{\theta}$, the REDD+ mechanism is a transfer $t(\hat{\theta})$ and a deforestation realized $d(\hat{\theta})$ that must verify participation of the country A and incentive compatibility. To this end, we draw on the revelation principle (Myerson (1979)) that ensures that direct mechanisms are sufficient to allow agents to reveal their real types θ. Participation will be ensured if (Participation Constraint (PC))

$$\begin{aligned} u(d(\hat{\theta})) + t(\hat{\theta}) - \psi(\theta - d(\hat{\theta})) &\geq u(\theta) \\ &\Leftrightarrow \; U(\theta, \hat{\theta}) = u(d(\hat{\theta})) + t(\hat{\theta}) - \psi(\theta - d(\hat{\theta})) - u(\theta) \geq 0 \end{aligned}$$

Incentive Compatibility Constraints (ICC) state that for all $\theta, \hat{\theta}$ (see Appendix 8.2 for global ICC)

$$U(\theta) \equiv U(\theta, \theta) \geq U(\theta, \hat{\theta})$$

Considering only differentiable contracts entails

$$\left.\frac{\partial U(\theta, \hat{\theta})}{\partial \theta}\right|_{\theta=\hat{\theta}} = -\psi'(\theta - d(\hat{\theta})) - u'(\theta)$$

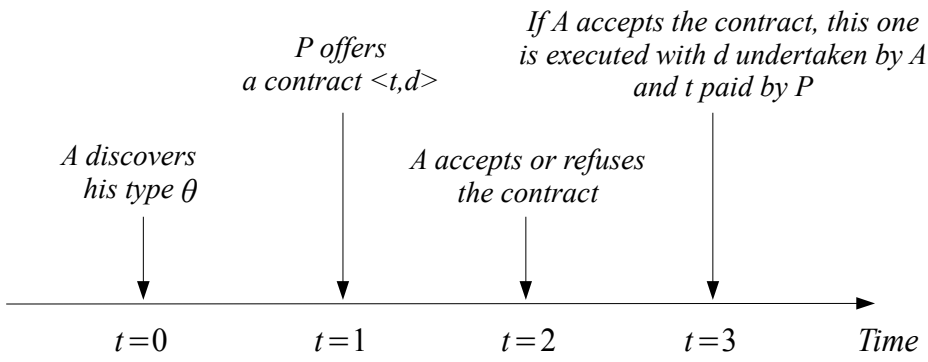

Figure 1. Contracting timing in the deforestation performance scheme

$$IC1 : U'(\theta) = -\psi'(\theta - d(\theta)) - u'(\theta) \leq 0$$

that is the marginal information rent, and thus rents are not increasing with θ. These incentive constraints are in line with the result in Lemma 1: to tackle RL agreements regarding overstatement incentives ($\hat{\theta} > \theta$) included in deforestation performance schemes, the P will give an information rent to low deforesting countries. As a result, the developing country net rent must decrease with the RL set.

From the marginal information rent, the information rent is for any θ

$$U(\theta) = U(\bar{\theta}) - \int_{\theta}^{\bar{\theta}} U'(\tau)d\tau = U(\bar{\theta}) + \int_{\theta}^{\bar{\theta}} \left[\psi'(\tau - d(\tau)) + u'(\tau)\right] d\tau$$

Local second order incentives imply that:[21]

$$IC2 : d'(\theta) \geq 0$$

To set correct incentives for the developing country, the deforestation allowed increases with the RL.[22]

The expected net surplus of P can be written as:

$$E(W) = \int_{\underline{\theta}}^{\bar{\theta}} \left[w(d(\theta)) - (1+\lambda)t(\theta) \right] f(\theta)\, d\theta$$

Substituting $t(\theta)$ and including expected information rents lead to write the country's decision program as:

$$\begin{aligned} \max_{d} & \int_{\underline{\theta}}^{\bar{\theta}} \{ w(d(\theta)) - (1+\lambda)\left[u(\theta) - u(d(\theta)) + \psi(\theta - d(\theta)) \right] \\ & \quad -(1+\lambda)\left[(\psi'(\theta - d(\theta)) + u'(\theta)) \right] \varphi(\theta) \} f(\theta)\, d\theta - (1+\lambda)U(\bar{\theta}) \\ \text{s.t.} & \begin{cases} U(\bar{\theta}) \geq 0 \\ IC2 : d'(\theta) \geq 0 \end{cases} \end{aligned}$$

From the following First Order Condition (FOC), one can define the second-best deforestation level $d^*(\theta)$ as the value of d such that:

$$w'(d) + (1+\lambda)\left[u'(d) + \psi'(\theta - d) \right] = -(1+\lambda)\psi''(\theta - d)\varphi(\theta) \tag{1}$$

Moreover as $-(1+\lambda)\psi''(\theta - d^*(\theta))\varphi(\theta) < 0$ then $d^*(\theta) \geq d^{FB}(\theta)$ where $d^{FB}(\theta)$ is defined in Section 3.

At the social optimum, our cost-benefit analysis can be explained such that:

[21] Since $\psi''(\theta - d(\theta))d'(\theta) \geq 0$.

[22] Expected information rents are given by (after by parts integration)

$$\int_{\underline{\theta}}^{\bar{\theta}} U(\theta) f(\theta)\, d\theta = U(\bar{\theta}) + \int_{\underline{\theta}}^{\bar{\theta}} \left(\psi'(\theta - d(\theta)) + u'(\theta) \right) F(\theta)\, d\theta$$

- $w'(d)$ is P's marginal cost or benefit associated with the deforestation level d. An increase (respectively a decrease) in d at the margin leads to reducing (resp. enhancing) P's gross utility.

- $(1+\lambda)\left[u'(d)+\psi'(\theta-d)\right]$ is A's marginal cost or benefit associated with the deforestation level d. An increase (respectively a decrease) in d at the margin leads to enhancing (resp. reducing) A's gross utility.

- $(1+\lambda)\psi''(\theta-d)\varphi(\theta)$ is the marginal information cost due to asymmetric information borne by P; as a cost, this increases the cost of the REDD+ policy.

The optimal transfer $t_d^*(\theta)$ can be stated as follows:

$$t_d^*(\theta) = U^*(\theta) - u(d^*(\theta)) + \psi(\theta - d^*(\theta)) + u(\theta)$$

This leads to the following proposition (see Appendix 8.3 for analytical results):

Proposition 2 *The REDD+ incentive compatible deforestation performance scheme entails:*

- *More deforestation than the first-best except for the lowest baseline announcement (no distortion at the bottom).*

- *There is no information rent left to the country responsible for most deforestation.*

- $d^*(\theta)$*, the optimal deforestation level with incomplete information increases strictly at the margin with the baseline announced;* $t_d^*(\theta)$ *the REDD+ optimal transfer decreases strictly.*

- *The avoided deforestation* $a(\theta) = \theta - d^*(\theta)$ *is not unambiguously increasing with* θ*. It decreases with* θ *if* $\varphi(\theta)$ *increases highly.*

In line with the standard theory of incentives, there is an information rent / efficiency trade-off within the REDD+ deforestation performance scheme. Deforestation levels must be distorted upwards for any developing country having $\theta > \underline{\theta}$ in order to minimize costly

information rents. If the REDD+ scheme promotes deforestation levels, the optimal scheme implies tackling forest areas where deforestation is *per se* the lowest. Information rents are awarded to countries with the lowest deforestation ($\underline{\theta}$) in order to incite them to induce the highest efficiency whilst coping with deforestation, while leaving other countries tending towards a higher deforestation level. A puzzling result emerges: the resulting avoided deforestation through effective domestic efforts may decrease with the RL announced. Again, this is due to asymmetric information: if the information cost $\varphi(\theta)$ increases strongly as baselines are higher announced, it could be optimal to design a deforestation scheme, that yields less reduction efforts, at least for some high types.

Another question is how the deforestation performance scheme depicted in Proposition 2 can be implemented. As discussed in Appendix 8.4, there exists an associated optimal schedule or menu of choices, which can be offered to the agent and which implements the same equilibrium outcome through decentralization. It can be designed as a decreasing non-linear transfer with respect to the deforestation level performed, $T(d)$. However it is not absolutely sure that it can be decentralized in linear contracts. Following Leplay *et al.* (2011), one could imagine implementing the REDD+ mechanism as a non-linear contract $T(d) = P(d).E.(\theta - d)$, where $P(d)$ would be a decreasing non-linear unit receipt based upon the observed international carbon price p: for example, as $P(d) = p - \gamma d$ with γ a scale factor, and E is the proxy carbon emissions factor, which converts deforestation into carbon emissions.

5 The conditional avoided deforestation scheme

This REDD+ mechanism is now built in such a way that when A and P agree on a RL $\hat{\theta}$, then P expects that A must carry out an effort to avoid deforestation of $a(\hat{\theta})$. The underlying idea is that deforestation reductions are "real" compensated successful efforts for avoided deforestation (Tacconi (2009), Combes-Motel *et al.* (2009)) or payments regarding conditionalities on the content of policies or measures (Karsenty and Ongolo (2012)). We use here observed avoided deforestation as cost observation (Laffont and Tirole (1986, 1993)) to

regulate developing countries, whilst preserving forests and respecting their commitment.

P offers a menu of contracts to A (take-it-or-leave-it offers) as $< t(\theta), a(\theta) >$ and the timing of the game is summarized in Figure 2.

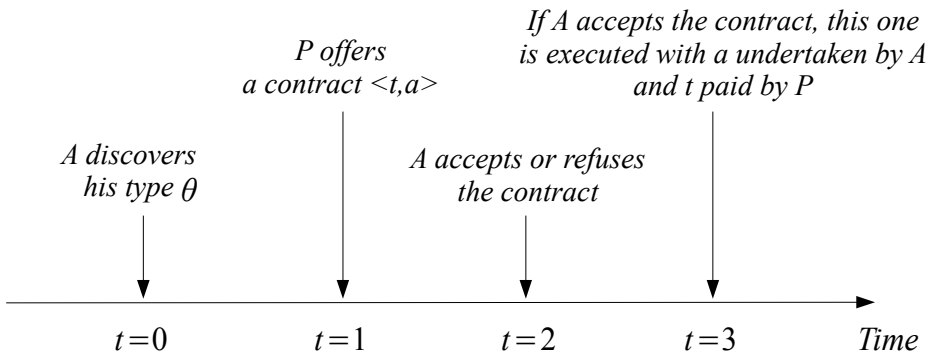

Figure 2. Contracting timing in the conditional avoided deforestation scheme

For a given RL $\hat{\theta}$, the REDD+ mechanism is a transfer $t(\hat{\theta})$ and an avoided deforestation $a(\hat{\theta})$ that must verify participation of the country and incentive compatibility.

Participation will be ensured if (Participation Constraint (PC))

$$\begin{aligned} u(\theta - a(\hat{\theta})) + t(\hat{\theta}) - \psi(a(\hat{\theta})) &\geq u(\theta) \\ &\Leftrightarrow V(\theta, \hat{\theta}) = u(\theta - a(\hat{\theta})) + t(\hat{\theta}) - \psi(a(\hat{\theta})) - u(\theta) \geq 0 \end{aligned}$$

Incentive Compatibility Constraints (ICC) state that for all $\theta, \hat{\theta}$ (see Appendix 8.5 for global

ICC)

$$V(\theta) \equiv V(\theta, \theta) \geq V(\theta, \hat{\theta})$$

Considering only differentiable contracts entails (by concavity of u)

$$\left.\frac{\partial V(\theta, \hat{\theta})}{\partial \theta}\right|_{\theta=\hat{\theta}} = u'(\theta - a(\hat{\theta})) - u'(\theta)$$

$$IC1 : V'(\theta) = u'(\theta - a(\theta)) - u'(\theta) \geq 0$$

that is the marginal information rent, and thus rents are not decreasing with θ. These incentive constraints are also in line with the result in Lemma 1: to tackle RL agreements regarding understatement incentives ($\hat{\theta} < \theta$) included in conditional avoided deforestation schemes, P will give an information rent to countries with much deforestation. As a result, the developing country's net rent must increase with the RL set.

Information rent is for any θ

$$V(\theta) = V(\underline{\theta}) + \int_{\underline{\theta}}^{\theta} V'(\tau) d\tau = V(\underline{\theta}) + \int_{\underline{\theta}}^{\theta} \left[u'(\tau - a(\tau)) - u'(\tau)\right] d\tau$$

Local second order incentives imply that:[23]

$$IC2 : a'(\theta) \geq 0$$

Avoided deforestation through effective efforts increases with the RL.[24]

The expected net surplus of P can be written as:

$$E\left(W\right) = \int_{\underline{\theta}}^{\bar{\theta}} \left[w(\theta - a\left(\theta\right)) - (1+\lambda)t(\theta)\right] f\left(\theta\right) d\theta$$

[23] Since $-a'(\theta)u''(\cdot) \geq 0$.

[24] Expected information rents are given by (after by parts integration)

$$\int_{\underline{\theta}}^{\bar{\theta}} V(\theta) f\left(\theta\right) d\theta = V(\underline{\theta}) + \int_{\underline{\theta}}^{\bar{\theta}} \left[u'(\theta - a(\theta)) - u'(\theta)\right] (1 - F(\theta)) d\theta$$

Substituting $t(\theta)$ and including expected rents leads writing its decision program as

$$\begin{aligned}
&\max_{a} \int_{\underline{\theta}}^{\bar{\theta}} \{w(\theta - a(\theta)) - (1+\lambda)\left[u(\theta) - u(\theta - a(\theta)) + \psi(a(\theta))\right] \\
&-(1+\lambda)\left[u'(\theta - a(\theta)) - u'(\theta)\right]\bar{\varphi}(\theta)\} f(\theta)d\theta - (1+\lambda)V(\underline{\theta}) \\
&\text{s.t.} \begin{cases} V(\underline{\theta}) \geq 0 \\ IC2 : a'(\theta) \geq 0 \end{cases}
\end{aligned}$$

One can state the optimal avoided deforestation $a^*(\theta)$ from the FOC as the value of a such that:

$$w'(\theta - a) + (1+\lambda)\left[u'(\theta - a) + \psi'(a)\right] = (1+\lambda)u''(\theta - a)\bar{\varphi}(\theta) \tag{2}$$

Moreover as $(1+\lambda)u''(\theta - a^*(\theta))\bar{\varphi}(\theta) < 0$ then $a^*(\theta) \leq a^{FB}(\theta)$ where $a^{FB}(\theta)$ is defined in Section 3.

At the social optimum, our cost-benefit analysis can be explained such that:

- $w'(\theta - a(\theta))$ is P's marginal loss or gain associated with the avoided deforestation a to cope with deforestation carried out by A. An increase (respectively decrease) in a at the margin leads to enhancing (resp. reducing) P's gross utility.

- $(1+\lambda)\left[u'(\theta - a(\theta)) + \psi'(a(\theta))\right]$ is A's marginal cost or benefit associated with its avoided deforestation a, to cope with deforestation. An increase (respectively a decrease) in a at the margin leads to reducing (resp. enhancing) A's gross utility.

- $(1+\lambda)u''(\theta - a(\theta))\bar{\varphi}(\theta)$ is the marginal information cost due to asymmetric information borne by P; as a cost, this increases the cost of the REDD+ policy.

The optimal transfer $t_a^*(\theta)$ can be stated as follows:

$$t_a^*(\theta) = V^*(\theta) - u(\theta - a^*(\theta)) + \psi(a^*(\theta)) + u(\theta)$$

This leads to the following proposition (see Appendix 8.6 for analytical results):

Proposition 3 *The REDD+ incentive compatible conditional avoided deforestation scheme entails:*

- *Less avoided deforestation than the first-best except for the highest baseline announcement (no distortion at the top).*
- *There is no information rent left to the least deforesting country.*
- $a^*(\theta)$*, the optimal avoided deforestation level with incomplete information and* $t_a^*(\theta)$ *the REDD+ optimal transfer are strictly increasing at the margin with the baseline announced.*
- *The resulting deforestation level* $d(\theta) = \theta - a^*(\theta)$ *does not increase unambiguously with* θ*. It decreases with* θ *if* $\bar{\varphi}(\theta)$ *decreases strongly.*

Our main result is thus that the information rent / efficiency trade-off in the REDD+ conditional avoided deforestation scheme does act in the opposite way as in the deforestation performance contract case. Avoided deforestation levels must be distorted downwards for any developing country having $\theta < \bar{\theta}$ ($a(\theta) < a(\bar{\theta})$), in order to minimize costly information rents. If the REDD+ scheme promotes conditional avoided deforestation levels, the optimal scheme implies tackling forest areas where deforestation is *per se* the highest. Information rents are awarded to forest areas with the highest deforestation $\left(\bar{\theta}\right)$, in order to encourage them to make the greatest effort $a\left(\bar{\theta}\right)$ and therefore efficiency to cope with deforestation, whilst leaving other countries to move towards higher deforestation.

We show in Appendix 8.7 that there also exists an associated optimal menu of choices which implements the same contract through decentralization. It can be designed as an increasing non-linear transfer with respect to the avoided deforestation level performed, $T(a)$, but again it is not absolutely sure that it can be decentralized with linear contracts. In the line of our discussion in the previous section, one could imagine implementing the REDD+ mechanism as a non-linear contract $T(a) = P(a).E.a$ where $P(a)$ would be an increasing non-linear unit receipt based upon the observed international carbon price, as $P(a) = p + \eta a$ with

η as a scale factor, and E as the proxy carbon emissions factor, which converts deforestation into carbon emissions.

6 Discussion

6.1 Contract choice, avoided deforestation and welfare

In this sub-section, we assess the environmental effectiveness of both contracts and we compare these contracts in terms of welfare gains and losses in a simple quadratic setting (see Appendix 8.8). The contract effectiveness is considered in the sense that deforestation is minimized. In this quadratic example, we consider that baseline types are uniformly distributed upon the support $\Theta = [1, 2]$, so that $\varphi(\theta) = \theta - 1$ and $\bar{\varphi}(\theta) = 2 - \theta$. Hence relevant variables d and a are defined in Θ. Surpluses are $w(d) = 8 - 3d^2$, $u(d) = (4 - d)d$ and the cost of avoided deforestation is $\psi(a) = \frac{a^2}{2}$. All these specific functions are chosen to obtain interior solutions to all outcomes and we assume also that $\lambda \leq \frac{1}{2}$. For clarity, one can see that $w(1) = 5 > \max u(d) = 4$, to illustrate the potential differential in country wealth. This leads to the following proposition:

Proposition 4 *In this simple uniform quadratic setting:*

1. *A baseline threshold $\tilde{\theta}$ exists such that:*
   - *if $\theta < \tilde{\theta}$, that is for countries with low intrinsic deforestation, the deforestation performance schemes are more effective than the conditional avoided deforestation schemes.*
   - *if $\theta > \tilde{\theta}$: for countries with high intrinsic deforestation, the conditional avoided deforestation schemes are more effective than the deforestation performance schemes.*
2. *A baseline threshold locus $\theta^*(\Lambda)$ exists, which decreases in Λ (where $\Lambda = \frac{1}{1+\lambda}$), such that the difference between the welfare obtained through the deforestation performance scheme and the welfare resulting from the conditional deforestation reduction effort scheme is positive if $\theta \geq \theta^*(\Lambda)$ and negative otherwise. Moreover $\theta^*(0) < \tilde{\theta}$.*

3. *The conditional avoided deforestation (CAD) reduction effort schemes are preferred to the deforestation performance schemes since expected welfare levels are higher.*

For a given θ, the sign of the difference between the welfare obtained through the deforestation performance (DP) scheme and the welfare resulting from the conditional deforestation reduction effort scheme depends on the level of the marginal cost of public funds in the Northern country (see Appendix 8.8). But as a whole, the expected welfare obtained through the conditional deforestation reduction effort contract is always greater than through the deforestation performance contract.

6.2 The political economy regarding States

The REDD+ scheme does not for the time encroach on Nations' sovereignty (Streck (2010)), and our analysis shows that conditionality for avoided deforestation is feasible and should be promoted. This supports theoretically the arguments of Combes-Motel *et al.* (2009) and Karsenty and Ongolo (2012). Consequently, a choice has to be made by a developed country with regards to the REDD+ phase it would finance, depending on the developing country it is facing. One may indeed stress that the REDD+ scheme achievement depends on a country's status whilst opposing "solid" *versus* "fragile" or "failed" States (Karsenty and Ongolo (2012)). "Fragile" States can be defined as States with failures regarding the rule of law, weak judiciary systems and limited government. In terms of forest-related policies, failures are the incapacity to carry out harvest limits or park protection, as well as the inability to reach commitments in international agreements on natural resource management (Irland (2008)).

As a consequence, considering environmental efficiency and the "degree of failures" regarding the failures stated above, this may lead to promoting conditionality on public policy levers (phase 2 funding) in order to ground the REDD+ scheme with regards to "Fragile" States. This would provide guidance and practical knowledge from Northern countries, whilst revisiting the relationships with governments in Southern countries to limit policy encroachment. This would also imply that reforms have to be sustained, and that REDD+ payments

have to be combined with other international public aid programs, to alter countries' development and induce structural changes. One may add that conditionality in development economics involves mainly five criteria with consequences: inducement; selectivity; paternalism; restraint; and, signalling (Collier *et al.* (1997)). It can be stressed that the inducement criterion does apply for our both incentive contracts, even though there is no altruism by the donor country in our setting, compared to a standard aid program for development (Collier *et al.* (1997), Ohler *et al.* (2012)).

Last, the RL is critical whilst dealing with a menu of contracts situation for a developed country, either on the deforestation level, or on the avoided deforestation level when this is observable. *A priori* the negotiation stage could reveal some information for the developed country. In Appendix 8.9 we develop a more realistic extension of our analysis in order to take into account the negotiated setting of the RL.

7 Conclusion

In this paper, we have demonstrated how the REDD+ scheme can be designed either through a performance-based contract or a conditionality-based contract to help avoid deforestation. Incomplete information as hidden information creates information rents on behalf of developing countries side that renders the REDD+ policy more costly and involves trade-offs, between the struggle over deforestation and information rents left to the developing countries. Our main results are that limiting deforestation and forest degradation should be incentive-based, whilst controlling effective domestic efforts in developing countries. Also taking implementation costs into account instead of only opportunity costs, explains why incentives and rents can act in opposite directions for each kind of contract. However discussion arises with regard to the political stability of the developing countries involved in REDD+ schemes. We can assert that conditionality is a principle that needs to be at the core of the REDD+ scheme's design with respect to developing countries to avoid deforestation, and we have shown that conditional avoided deforestation contracts are feasible and suitable when avoided deforestation is observable. Moreover, States have to be assessed by the international

community to propose the most suitable way to implement the REDD+ scheme.

Last, several methodological aspects have to be solved for an effective REDD+ implementation and to allow conditionality: the permanence of any achieved storage has to be ensured; there is a need for Monitoring, Reporting and Verification (MRV) systems to increase the building of capacity; and, there is a need of credible carbon accounting (Lederer (2011)). Furthermore, development and environmental issues have to be taken into account, as there are trade-offs between poverty alleviation and climate mitigation. We may add that local projects through Payments for Environmental Services (PES) have to be enhanced with direct relationships between developed countries, local populations and NGOs. This local level of application would be suitable in these States even though initial projects have experienced corruption, nepotism and pressure on local populations (Lederer (2011)). Moreover, a disintermediation of current players in the tropical timber market has to be accepted in order to protect forests, to increase populations' standards of living and to alleviate poverty (Heal and Conrad (2006)).

8 Appendix

8.1 Proof of Lemma 1

Starting from the FB contract menu of (equivalent) contracts $\left\langle d^{FB}(\hat{\theta}), t^{FB}(\hat{\theta})\right\rangle_{\hat{\theta}\in\Theta}$ or $\left\langle a^{FB}(\hat{\theta}), t^{FB}(\hat{\theta})\right\rangle_{\hat{\theta}\in\Theta}$ if the agent chooses to apply $d^{FB}(\hat{\theta})$ in the contract (that is the real effort will be $a(\theta,\hat{\theta}) = \theta - d^{FB}(\hat{\theta})$) then

$$\mathcal{U}(\theta,\hat{\theta}) = u(d^{FB}(\hat{\theta})) - \psi(\theta - d^{FB}(\hat{\theta})) - u(\theta) + \psi(a^{FB}(\hat{\theta})) + u(\hat{\theta}) - u(d^{FB}(\hat{\theta}))$$

which is increasing if $\hat{\theta} = \theta$ as

$$\mathcal{U}'_{\hat{\theta}}(\theta,\hat{\theta}) = d^{FB\prime}(\hat{\theta})\psi'(\theta - d^{FB}(\hat{\theta})) + a^{FB\prime}(\hat{\theta})\psi'(a^{FB}(\hat{\theta})) + u'(\hat{\theta})$$

so $\mathcal{U}'_{\hat{\theta}}(\theta,\theta) = \psi'(a^{FB}(\theta)) + u'(\theta) > 0$. As a result, deforesting agents are likely to overstate their baseline announcement ($\hat{\theta} > \theta$).

However if the agent chooses to apply $a^{FB}(\hat{\theta})$ (then $d(\theta,\hat{\theta}) = \theta - a^{FB}(\hat{\theta})$) then

$$\mathcal{U}(\theta,\hat{\theta}) = u(\theta - a^{FB}(\hat{\theta})) - \psi(a^{FB}(\hat{\theta})) - u(\theta) + \psi(a^{FB}(\hat{\theta})) + u(\hat{\theta}) - u(d^{FB}(\hat{\theta}))$$

which is decreasing if $\hat{\theta} = \theta$ as

$$\mathcal{U}'_{\hat{\theta}}(\theta,\hat{\theta}) = -a^{FB\prime}(\hat{\theta})\left[u(\theta - a^{FB}(\hat{\theta})) - u'(d^{FB}(\hat{\theta}))\right] + u'(\hat{\theta}) - u'(d^{FB}(\hat{\theta}))$$

so $\mathcal{U}'_{\hat{\theta}}(\theta,\theta) = u'(\theta) - u'(d^{FB}(\theta)) < 0$ since $u'(\cdot)$ is decreasing and $\theta \geq d^{FB}(\theta)$. As a result, agents are likely to understate their baseline announcement ($\hat{\theta} < \theta$).

8.2 Global Incentive Compatibility Constraint (ICC) with the deforestation performance scheme

Using a standard revealed preference argument, this leads to the global ICC:

$$\begin{aligned} u(d(\theta)) + t(\theta) - \psi(\theta - d(\theta)) - u(\theta) &\geq u(d(\hat{\theta})) + t(\hat{\theta}) - \psi(\theta - d(\hat{\theta})) - u(\theta) \\ u(d(\hat{\theta})) + t(\hat{\theta}) - \psi(\hat{\theta} - d(\hat{\theta})) - u(\hat{\theta}) &\geq u(d(\theta)) + t(\theta) - \psi(\hat{\theta} - d(\theta)) - u(\hat{\theta}) \end{aligned}$$

add up and yields

$$\psi(\hat{\theta} - d(\theta)) - \psi(\theta - d(\theta)) \geq \psi(\hat{\theta} - d(\hat{\theta})) - \psi(\theta - d(\hat{\theta})) \Leftrightarrow \int_{\theta}^{\hat{\theta}} \int_{d(\theta)}^{d(\hat{\theta})} \psi''(x-y)dydx \geq 0$$

Hence $\psi''(\cdot) \geq 0$ if $\hat{\theta} > \theta$ then $d(\hat{\theta}) > d(\theta)$: $d(\cdot)$ is a non decreasing function of θ.

8.3 Optimal contract with the deforestation performance scheme

Proof of Proposition 1.

Following the FOC, the REDD+ incentive compatible deforestation scheme entails:

- There is no information rent left to the country with most deforestation as $U(\bar{\theta}) = 0$ at the optimum.

- $d^*(\theta)$ is the solution in d of (1) so that $d^*(\theta) \geq d^{FB}(\theta)$ as the marginal information cost is $(1+\lambda)\psi''(\theta - d)\varphi(\theta) > 0$.

- There is no distortion at the bottom as $d^*(\underline{\theta}) = d^{FB}(\underline{\theta})$ (as $\varphi(\underline{\theta}) = 0$).

- $d^*(\theta)$ is strictly increasing at the margin (as $\psi''' > 0$) with the baseline announced. Indeed from (1), one can differentiate and show that

$$d^{*\prime}(\theta) = \frac{\psi''(\theta - d)\left[1 + \varphi'(\theta)\right] + \psi'''(\theta - d)\varphi(\theta)}{\psi''(\theta - d) + \psi'''(\theta - d)\varphi(\theta) - \frac{w''(d)}{1+\lambda} - u''(d)} > 0$$

  However one cannot exclude the case for which $d^{*\prime}(\theta) \geq 1$, so $a(\theta)$ is not unambiguously increasing. This is not the case if

$$\psi''(\theta - d^*(\theta))\varphi'(\theta) + \frac{w''(d^*(\theta))}{1+\lambda} + u''(d^*(\theta)) \geq 0$$

  that is if $\varphi(\theta)$ is highly increasing (or w and u slightly concave).

- REDD+ optimal transfer t_d^* is decreasing at the margin with the baseline announced. The optimal transfer $t_d^*(\theta)$ can be stated as follows:

$$t_d^*(\theta) = U^*(\theta) - u(d^*) + \psi(\theta - d^*(\theta)) + u(\theta)$$

  so that

$$t_d^{*\prime}(\theta) = -\left[u'(d^*) + \psi'(\theta - d^*(\theta))\right] d'(\theta) < 0$$

8.4 Implementation of the deforestation performance scheme

Using an equivalent of the taxation principle (Hammond (1979), Guesnerie (1981, 1995)), then for any truth-telling, direct-revelation scheme, there exists an associated schedule or menu of choices which can be offered to the agent and which implements the same equilibrium

outcome through decentralization. One can see that the deforestation performance transfer can be implemented as with a decreasing contract. Indeed inverting $d^*(\theta)$, as an increasing function, yields $\theta^*(d)$ and substituting in $t_d^*(\theta)$:

$$t_d^*(\theta^*(d)) = U^*(\theta^*(d)) - u(d) + \psi(\theta^*(d) - d) + u(\theta^*(d)) \equiv T(d)$$

where $T(d)$ is then the optimal transfer as a function of the observed deforestation level. It is a decreasing function of d but this is not certainly convex, as the corresponding effort a is does not incrreases unambiguously. Indeed $T'(d) = t_d'^*(\theta)\,\theta^{*\prime}(d) = -[u'(d) + \psi'(\theta - d)] < 0$ and $T''(d) = -u''(d) - \psi''(\theta - d)[\theta^{*\prime}(d) - 1]$ does not have a constant sign.

8.5 Global Incentive Compatibility Constraint (ICC) with the conditional avoided deforestation scheme

Using a standard revealed preference argument, this leads to the global ICC:

$$\begin{aligned} u(\theta - a(\theta)) + t(\theta) - \psi(a(\theta)) - u(\theta) &\geq u(\theta - a(\hat{\theta})) + t(\hat{\theta}) - \psi(a(\hat{\theta})) - u(\theta) \\ u(\hat{\theta} - a(\hat{\theta})) + t(\hat{\theta}) - \psi(a(\hat{\theta})) - u(\hat{\theta}) &\geq u(\hat{\theta} - a(\theta)) + t(\theta) - \psi(a(\theta)) - u(\hat{\theta}) \end{aligned}$$

and by summing yields

$$u(\theta - a(\theta)) - u(\hat{\theta} - a(\theta)) \geq u(\theta - a(\hat{\theta})) - u(\hat{\theta} - a(\hat{\theta})) \Leftrightarrow -\int_{\theta}^{\hat{\theta}} \int_{d(\theta)}^{d(\hat{\theta})} u''(x - y)dxdy \geq 0$$

Hence since $u''(\cdot) \leqslant 0$ if $\hat{\theta} > \theta$ then $a(\hat{\theta}) > a(\theta)$: $a(\theta)$ is a non-decreasing function of θ.

8.6 Optimal contracts with the conditional avoided deforestation scheme

Proof of Proposition 2.

Following the FOC, the REDD+ incentive compatible conditional deforestation reducing

effort scheme entails:

- There is no information rent left to the country with least deforestation as $V(\underline{\theta}) = 0$ at the optimum.

- $a^*(\theta)$ is the solution in a of (2) so that $a^*(\theta) \leq a^{FB}(\theta)$ as the marginal information cost is $(1+\lambda)u''(\theta - a(\theta))\bar{\varphi}(\theta) < 0$.

- There is no distortion at the top as $a^*(\bar{\theta}) = a^{FB}(\bar{\theta})$ (as $\bar{\varphi}\left(\bar{\theta}\right) = 0$).

- $a^*(\theta)$ is strictly increasing at the margin with the baseline announced. Indeed differentiating (2) leads to

$$a^{*\prime}(\theta) = \frac{\frac{w''(\theta-a)}{1+\lambda} + u''(\theta-a)\left(1-\bar{\varphi}'(\theta)\right) - u'''(\theta-a)\bar{\varphi}(\theta)}{\frac{w''(\theta-a)}{1+\lambda} + u''(\theta-a) - \psi''(a) - u'''(\theta-a)\bar{\varphi}(\theta)} > 0$$

  Again one cannot exclude the case for which $a^{*\prime}(\theta) \geq 1$, so $d(\theta)$ is not unambiguously increasing. This is not the case if

$$u''(\theta - a^*(\theta))\bar{\varphi}'(\theta) - \psi''(a^*(\theta)) \geq 0$$

  that is if $\bar{\varphi}'(\theta)$ is highly decreasing.

- REDD+ optimal transfer t_a^* is increasing at the margin with the baseline announced. The optimal transfer t_a^* can be stated as follows:

$$t_a^*(\theta) = V^*(\theta) - u(\theta - a^*(\theta)) + \psi(a^*(\theta)) + u(\theta)$$

  and

$$t_a^{*\prime}(\theta) = \left[u'(\theta - a^*(\theta)) + \psi'(a^*(\theta))\right] a'(\theta) > 0$$

8.7 Implementation of the conditional avoided deforestation scheme

As in Appendix 8.4, inverting $a^*(\theta)$ as an increasing function yields $\theta^*(a)$, and substituting in $t_a^*(\theta)$ yields

$$t_a^*(\theta^*(a)) = V^*(\theta^*(a)) - u(\theta^*(a) - a) + \psi(a) + u(\theta^*(a)) \equiv T(a)$$

It is an increasing function of a but this is not certainly convex as the corresponding deforestation level d does not increase unambiguously. Indeed $T'(a) = t_a'^*(\theta)\,\theta^{*\prime}(a) = u'(\theta - a) + \psi'(a) > 0$ and $T''(a) = [\theta^{*\prime}(a) - 1]\,u''(\theta - a) + \psi''(a)$ does not have a constant sign as $\theta^{*\prime}(a)$ is not unambiguously greater or less than 1.

8.8 Contract comparison in a specific setting

Consider that baseline types are distributed upon the support $[1, 2]$ according to a uniform law, so that $\varphi(\theta) = \theta - 1$ and $\bar{\varphi}(\theta) = 2 - \theta$, surplus are $w(d) = 8 - 3d^2$, $u(d) = (4 - d)d$ and $\psi(a) = \frac{a^2}{2}$. Hence for the First-Best, we have with $\Lambda = \frac{1}{1+\lambda} \in [0, 1]$, $a^{FB}(\theta) = \frac{2}{3}\frac{(3\Lambda+1)\theta-2}{2\Lambda+1}$ and $d^{FB}(\theta) = \frac{1}{3}\frac{\theta+4}{2\Lambda+1}$. The deforestation performance scheme yields $d^*(\theta) = \frac{1}{3}\frac{2\theta+3}{2\Lambda+1}$ so avoided deforestation is $\hat{a}^*(\theta) = \frac{1}{3}\frac{(6\Lambda+1)\theta-3}{2\Lambda+1}$. Finally the conditional avoided deforestation scheme is $a^*(\theta) = \frac{2}{3}\frac{(3\Lambda+2)\theta-4}{2\Lambda+1} \geq 0$, for all θ if $\Lambda \geq \frac{2}{3}$ that is $\lambda \leq \frac{1}{2}$; the resulting deforestation level (or rate) is $\hat{d}^*(\theta) = \frac{1}{3}\frac{8-\theta}{2\Lambda+1}$. An example where $\hat{d}^*(\theta)$ is decreasing.

Hence it exists a baseline threshold $\tilde{\theta}$ exists with $\tilde{\theta} = \frac{5}{3} : d^*\left(\tilde{\theta}\right) = \hat{d}^*\left(\tilde{\theta}\right)$ and $a^*\left(\tilde{\theta}\right) = \hat{a}^*\left(\tilde{\theta}\right)$ and:

- if $\theta < \tilde{\theta} : d^*(\theta) < \hat{d}^*(\theta)$ and $\hat{a}^*(\theta) > a^*(\theta)$: Deforestation performance schemes are more effective
- if $\theta > \tilde{\theta} : \hat{d}^*(\theta) < d^*(\theta)$ and $\hat{a}^*(\theta) < a^*(\theta)$: Conditional avoided deforestation schemes are more effective

The following figures illustrate under our three situations, *i.e.*, First-Best Scheme (FBS), the Deforestation Performance Scheme (DPS), the Conditional Avoided Deforestation Scheme

(CADS) respectively: the deforestation evolution $d(\theta)$ (Figure 3), the avoided deforestation evolution $a(\theta)$ (Figure 4) and the transfer evolution $t(\theta)$ (Figure 5) [θ on the X axis; red: FBS, black = DPS, and blue = CADS on the Y axis]

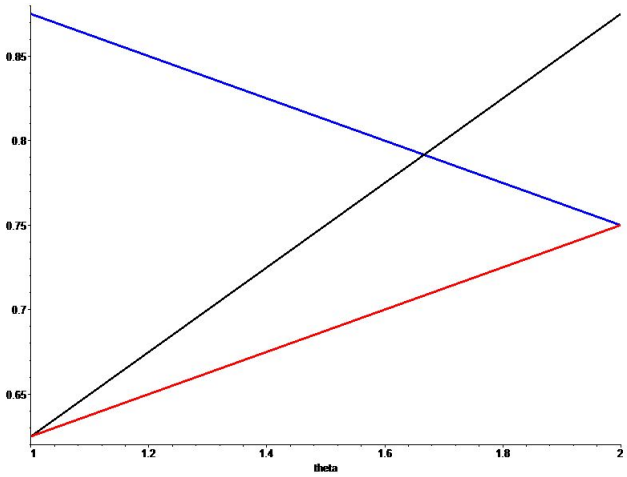

Figure 3: Deforestation evolvement $d(\theta)$

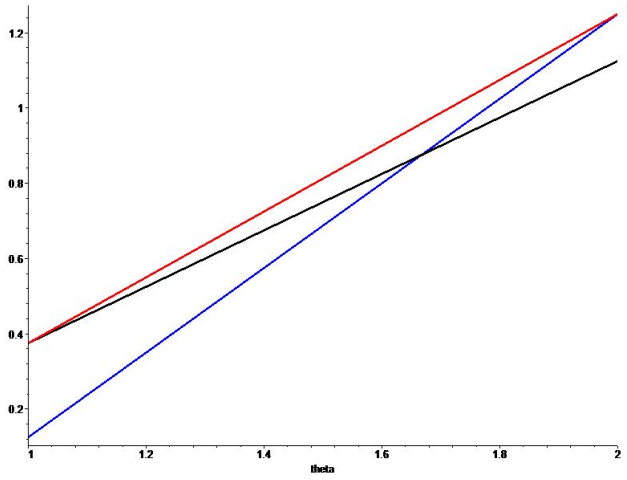

Figure 4: Avoided deforestation $a(\theta)$

Let us compute the first-best welfare and the second-best welfare for each scheme and each type, respectively the deforestation performance and the conditional avoided deforestation

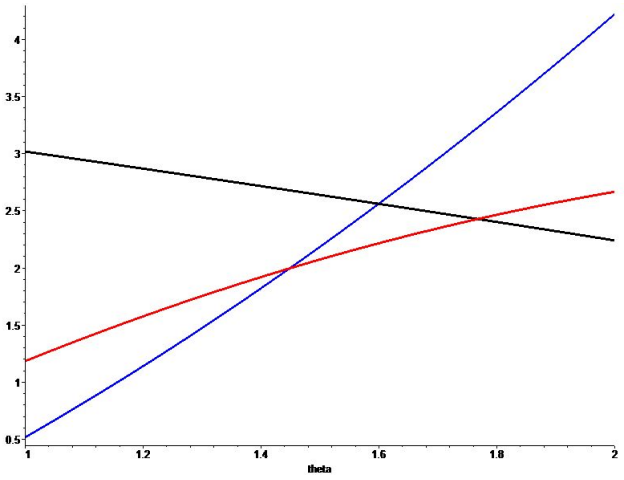

Figure 5: Transfer evolvement $t(\theta)$

schemes :

$$\begin{aligned} W^{FB}(\theta) &= \frac{1}{3(2\Lambda+1)\Lambda}\left[(3\Lambda+2)\theta^2-(8+24\Lambda)\theta+48\Lambda^2+24\Lambda+8\right] \\ W^{DP}(\theta) &= \frac{1}{6(2\Lambda+1)\Lambda}\left[(18\Lambda+13)\theta^2-(42+108\Lambda)\theta+96\Lambda^2+96\Lambda+33\right] \\ W^{CA}(\theta) &= \frac{1}{3(2\Lambda+1)\Lambda}\left[(15\Lambda+8)\theta^2-(48\Lambda+32)\theta+48\Lambda^2+24\Lambda+32\right] \end{aligned}$$

Instead of computing the welfare loss in each case and comparing these losses, we directly compute the difference between the two second-best welfare levels. Let:

$$\Delta W(\theta) = W^{DP}(\theta) - W^{CA}(\theta) = \frac{1}{6(2\Lambda+1)\Lambda}\left[(12\Lambda+3)\theta^2+(22-12\Lambda)\theta+48\Lambda-31\right]$$

This difference is zero for a given $\theta^*(\Lambda) = \frac{11-6\Lambda-2\sqrt{153\Lambda^2-90\Lambda+7}}{3(4\Lambda+1)}$ which is in Θ for $\Lambda \geq \frac{2}{3}$.[25] Hence as a concave second order polynomial function of θ, $\Delta W(\theta) \geq 0$ if $\theta \geq \theta^*(\Lambda)$ and negative otherwise. Moreover $\theta^*\left(\frac{2}{3}\right) = \frac{7+2\sqrt{15}}{11} \simeq 1.34 < \frac{5}{3}$. One can compute expected welfare

[25]The other (negative) root is less than $\bar{\theta} = 1$ for $\Lambda \geq \frac{2}{3}$.

levels, they are simply determined by

$$\begin{aligned} E\left(W^{FB}(\theta)\right) &= \frac{144\Lambda^2 - 15\Lambda + 2}{9(2\Lambda+1)\Lambda} \\ E\left(W^{DP}(\theta)\right) &= \frac{288\Lambda^2 - 12\Lambda + 1}{18(2\Lambda+1)\Lambda} \\ E\left(W^{CA}(\theta)\right) &= \frac{144\Lambda^2 - 39\Lambda + 8}{9(2\Lambda+1)\Lambda} \end{aligned}$$

then here $E\left(W^{DP}(\theta)\right) \leq E\left(W^{CA}(\theta)\right)$ as $E(\Delta W(\theta)) = \frac{2\Lambda-5}{9(2\Lambda+1)\Lambda}$ which is negative for admissible values of Λ.

8.9 Assessing the deforestation baseline

Most of the time, REDD+ schemes assume that a prior bargaining process is engaged between the North and the South to determine what is the deforestation baseline for a given country. Figuières *et al.* (2012) analyze this process in a game-theoretic bargaining model and show some caveats of the REDD mechanisms in a context of perfect information. Of course, this negotiation stage will reveal some information for the North and could be considered as a solution to the adverse selection problem (hidden information) we have studied. However, it has been shown in the case of the Guyanan "economically-rational" deforestation baseline that countries are ready to invest in some falsification strategies of forest core information (Karsenty and Ongolo (2012)). Following Maggi and Rodriguez (1995), it is assumed that a prior stage can take place between P and A, in order to decide what the RL entering in the REDD+ scheme would be, so that now the *ex post* deforestation level d is defined as $d(b,a) = b - a$ where b is the RL negotiated. Hence REDD+ might now be designed as $< t(b), d(b) >$ for deforestation performance schemes and $< t(b), a(b) >$ for conditional avoided deforestation schemes. For a given country with baseline $\theta \in \Theta$ whose realization is observed before signing the contract within the negotiation meeting, P observes a signal of the RL, $b = \theta + \alpha$ where $\alpha \in \mathbb{R}$ is an unobservable action that A can take to distort the RL signalled, in either direction. The cost of falsification associated α is $\phi(\alpha)$ is a convex function. With $\alpha = b - \theta$, A's utility can be written as $U = u(d) + t - \psi(\theta - d) - \phi(b - \theta)$

for deforestation performance schemes and $V = u(\theta - a) + t - \psi(a) - \phi(b - \theta)$ for conditional avoided deforestation schemes.

By the revelation principle we can derive optimal contracts as an allocation $< t(\theta), d(\theta), b(\theta) >$ and for the deforestation performance schemes case, ICC entails both

$$\begin{aligned} IC1 &: U'(\theta) = -\psi'(\theta - d(\theta)) - u'(\theta) + \phi'(b(\theta) - \theta) \lesseqgtr 0 \\ IC2 &: d'(\theta) \geq 0 \text{ and } b'(\theta) \geq 0. \end{aligned}$$

For conditional avoided deforestation schemes, ICC implies both

$$\begin{aligned} IC1 &: V'(\theta) = u'(\theta - a(\theta)) - u'(\theta) + \phi'(b(\theta) - \theta) \lesseqgtr 0 \\ IC2 &: a'(\theta) \geq 0 \text{ and } b'(\theta) \geq 0. \end{aligned}$$

Without deriving the exact optimal allocations, one can highlight several features of RL falsification. Incentives are clearly affected by the falsification abilities; consequently optimal schemes are expected to be modified because of the cost of disinformation. Rents do not then decrease unambiguously and monotonically for all schemes. Some countervailing incentives may appear: because of costly falsification, for some RL levels it may be the case that developing countries have some incentives to understate their RL rate in deforestation performance schemes. Similarly, they might be compelled to overstate their types in conditional avoided deforestation schemes. As a result, it might be possible that pooling contracts arise: it could be optimal for the donor to propose the same contract for a set of countries with different RL levels.

References

[1] Angelsen, A., 2008. REDD models and baselines. *International Forestry Review*. 10(3), 465-475.

[2] Chiroleu-Assouline M. and Roussel S., 2010. Contract Design to Sequester Carbon

in Agricultural Soils. *CES Working Papers, Université Paris 1 Panthéon-Sorbonne*. 2010.60.

[3] Collier P, Guillaumont P., Guillaumont S. and Gunning J.W., 1997. Redesigning Conditionality. *World Development*. 25(9), 1399-1407.

[4] Combes-Motel P., Pirard R. and Combes J.-L., 2009. A Methodology to Estimate Impacts of Domestic Policies on Deforestation: Compensated Successful Efforts for "Avoided Deforestation" (REDD). *Ecological Economics*. 68(3), 680-691.

[5] Crampes C., 1983. Subventions et régulation d'une entreprise privée. *Annales de l'INSEE.* 51, 47-64.

[6] Delacote P. and Simonet G., 2012. Readiness and Avoided Deforestation Policies: on Spending the REDD Fund, *Miméo.*

[7] Ekins P., Kesicki F. and Smith A.Z.P., 2011. Marginal Abatement Costs Curves: A Call for Caution. London, UK: University College London.

[8] Eliasch J., 2008. Eliasch Review: Climate Change: Financing Global Forests. Office of the Prime Minister, London.

[9] Figuières C. and Midler E., 2011. Deforestation as an Externality Problem to be solved Efficiently and Fairly. *Working Papers, LAMETA*. 2011.17.

[10] Figuières C., Leplay S., Midler E. and Thoyer S., 2012. The REDD Scheme to Curb Deforestation: a Well-Designed System of Incentives? *Strategic Behavior and the Environment* (In Press).

[11] Gregersen, H., El Lakany, H., Karsenty, A. and White, A., 2010. Does the Opportunity Cost Approach Indicate the Real Cost of REDD+? Rights and Realities of Paying for REDD+. Rights and Resources Initiative, Washington, DC.

[12] Guesnerie R., 1981. On Taxation and Incentives. Further Remarks on the Limits to Redistribution. *Bonn Discussion Paper*. 89.

[13] Guesnerie R., 1995. *A Contribution to the Pure Theory of Taxation*. Cambridge University Press, Cambridge.

[14] Hammond P., 1979. Straightforward Incentive Compatibility in Large Economies. *Review of Economic Studies.* 46, 263-282.

[15] Heal G. and Conrad K., 2006. Incentive to Reduce Tropical Deforestation (Editorial). *Journal of Forest Economics*. 11, 201-203.

[16] Intergovernmental Panel on Climate Change (IPCC), 2007a. Climate Change 2007 — Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge.

[17] Intergovernmental Panel on Climate Change (IPCC), 2007b. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge.

[18] Irland L.C., 2008. State Failure, Corruption, and Warfare: Challenges for Forest Policy. *Journal of Sustainable Forestry*. 27(3), 189-223.

[19] Karsenty A. and Ongolo S., 2012. Can "Fragile States" Decide to Reduce their Deforestation? The Inappropriate Use of the Theory of Incentives with respect to the REDD Mechanism. *Forest Policy and Economics*. 18, 38-45.

[20] Kindermann G., Obersteiner M., Sohngen B., Sathaye J., Andrasko K., Rametsteiner E., Schlamadinger B., Wunder S. and Beach R., 2008. Global Cost Estimates of Reducing Carbon Emissions through Avoided Deforestation. *Proceedings of the National Academy of Sciences (PNAS).* 105, 10302-10307.

[21] Laffont J.-J. and Martimort D., 2002. The Theory of Incentives: the Principal-Agent Model. Princeton University Press.

[22] Laffont J.-J. and Tirole J., 1986. Using Cost Observation to Regulate Firms. *Journal of Political Economy*. 94(3), 614-641.

[23] Laffont J.-J. and Tirole J., 1993. A Theory of Incentives in Procurement and Regulation. The MIT Press.

[24] Lederer M., 2011. From CDM to REDD+ — What Do We Know for Setting up Effective and Legitimate Carbon Governance? *Ecological Economics*. 70, 1900-1907.

[25] Leplay S., Busch J., Delacote P. and Thoyer S., 2011. Implementation of National and International REDD Mechanism under Alternative Payments for Environmental Services: Theory and Illustration from Sumatra. *Working Papers, LAMETA*. 2011.02.

[26] Maskin, E. and Riley, J. 1985. Input Versus Output Incentive Schemes. *Journal of Public Economics*. 28, 1-23.

[27] Maggi G. and Rodriguez-Clare A., 1995. Costly Distortion of Information in Agency Problems. *RAND Journal of Economics*. 26(4), 675-689.

[28] Murray B.C., Lubowski R. and Sohngen B., 2009. Including International Forest Carbon Incentives in Climate Policy: Understanding the Economics, NI R 09-03 Nicholas Institute for Environmental Policy Solutions, Duke University, Durham, NC, 63p.

[29] Myerson R.B., 1979. Incentive Compatibility and the Bargaining Problem. *Econometrica*. 47, 61-74.

[30] Ohler H., Nunnenkamp P. and Dreher A., 2012. Does Conditionality Work? A Test for an Innovative US Aid Scheme. *European Economic Review*. 56, 138-153.

[31] Samuelson W., 1984. Bargaining under Asymmetric Information. *Econometrica*. 4, 995-1005.

[32] Streck C., 2010. Reducing Emissions from Deforestation and Forest Degradation: National Implementation of REDD schemes (an Editorial Comment). *Climatic Change*. 100, 389-394.

[33] Tacconi L., 2009. Compensated Successful Efforts for Avoided Deforestation vs Compensated Reductions. *Ecological Economics*. 68(8/9), 2469-2472.

[34] Van der Werf, G.R., Morton, D.C., DeFries, R., Olivier, J.G.J., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J. and Randerson, J.T., 2009. CO2 Emissions from Forest Loss. *Nature Geoscience*. 2, 737-738.

[35] Varian H.R., 1994. A Solution to the Problem of Externalities when Agents are Well-Informed. *American Economic Review*. 84(5), 1278-1293.

[36] Zarin, D., Angelsen, A., Brown, S., Loisel, C., Peskett, L. and Streck, C., 2009. Reducing Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report. Meridian Institute.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

http://www.feem.it/getpage.aspx?id=73&sez=Publications&padre=20&tab=1
http://papers.ssrn.com/sol3/JELJOUR_Results.cfm?form_name=journalbrowse&journal_id=266659
http://ideas.repec.org/s/fem/femwpa.html
http://www.econis.eu/LNG=EN/FAM?PPN=505954494
http://ageconsearch.umn.edu/handle/35978
http://www.bepress.com/feem/

NOTE DI LAVORO PUBLISHED IN 2012

CCSD	1.2012	Valentina Bosetti, Michela Catenacci, Giulia Fiorese and Elena Verdolini: The Future Prospect of PV and CSP Solar Technologies: An Expert Elicitation Survey
CCSD	2.2012	Francesco Bosello, Fabio Eboli and Roberta Pierfederici: Assessing the Economic Impacts of Climate Change. An Updated CGE Point of View
CCSD	3.2012	Simone Borghesi, Giulio Cainelli and Massimiliano Mozzanti: Brown Sunsets and Green Dawns in the Industrial Sector: Environmental Innovations, Firm Behavior and the European Emission Trading
CCSD	4.2012	Stergios Athanassoglou and Valentina Bosetti and Gauthier de Maere d'Aertrycke: Ambiguous Aggregation of Expert Opinions: The Case of Optimal R&D Investment
CCSD	5.2012	William Brock, Gustav Engstrom and Anastasios Xepapadeas: Energy Balance Climate Models and the Spatial Structure of Optimal Mitigation Policies
CCSD	6.2012	Gabriel Chan, Robert Stavins, Robert Stowe and Richard Sweeney: The SO2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation
ERM	7.2012	Claudio Morana: Oil Price Dynamics, Macro-Finance Interactions and the Role of Financial Speculation
ES	8.2012	Gérard Mondello: The Equivalence of Strict Liability and Negligence Rule: A « Trompe l'œil » Perspective
CCSD	9.2012	Eva Schmid, Brigitte Knopf and Nico Bauer: REMIND-D: A Hybrid Energy-Economy Model of Germany
CCSD	10.2012	Nadia Ameli and Daniel M. Kammen: The Linkage Between Income Distribution and Clean Energy Investments: Addressing Financing Cost
CCSD	11.2012	Valentina Bosetti and Thomas Longden: Light Duty Vehicle Transportation and Global Climate Policy: The Importance of Electric Drive Vehicles
ERM	12.2012	Giorgio Gualberti, Morgan Bazilian, Erik Haites and Maria da Graça Carvalho: Development Finance for Universal Energy Access
CCSD	13.2012	Ines Österle: Fossil Fuel Extraction and Climate Policy: A Review of the Green Paradox with Endogenous Resource Exploration
ES	14.2012	Marco Alderighi, Marcella Nicolini and Claudio A. Piga: Combined Effects of Load Factors and Booking Time on Fares: Insights from the Yield Management of a Low-Cost Airline
ERM	15.2012	Lion Hirth: The Market Value of Variable Renewables
CCSD	16.2012	F. Souty, T. Brunelle, P. Dumas, B. Dorin, P. Ciais and R. Crassous: The Nexus Land-Use Model, an Approach Articulating Biophysical Potentials and Economic Dynamics to Model Competition for Land-Uses
CCSD	17.2012	Erik Ansink, Michael Gengenbach and Hans-Peter Weikard: River Sharing and Water Trade
CCSD	18.2012	Carlo Carraro, Enrica De Cian and Massimo Tavoni: Human Capital, Innovation, and Climate Policy: An Integrated Assessment
CCSD	19.2012	Melania Michetti and Ramiro Parrado: Improving Land-use modelling within CGE to assess Forest-based Mitigation Potential and Costs
CCSD	20.2012	William Brock, Gustav Engstrom and Anastasios Xepapadeas: Energy Balance Climate Models, Damage Reservoirs and the Time Profile of Climate Change Policy
ES	21.2012	Alireza Naghavi and Yingyi Tsai: Cross-Border Intellectual Property Rights: Contract Enforcement and Absorptive Capacity
CCSD	22.2012	Raphael Calel and Antoine Dechezleprêtre: Environmental Policy and Directed Technological Change: Evidence from the European carbon market
ERM	23.2012	Matteo Manera, Marcella Nicolini and Ilaria Vignati: Returns in Commodities Futures Markets and Financial Speculation: A Multivariate GARCH Approach
ERM	24.2012	Alessandro Cologni and Matteo Manera: Oil Revenues, Ethnic Fragmentation and Political Transition of Authoritarian Regimes
ERM	25.2012	Sanya Carley, Sameeksha Desai and Morgan Bazilian: Energy-Based Economic Development: Mapping the Developing Country Context
ES	26.2012	Andreas Groth, Michael Ghil, Stéphane Hallegatte and Patrice Dumas: The Role of Oscillatory Modes in U.S. Business Cycles
CCSD	27.2012	Enrica De Cian and Ramiro Parrado: Technology Spillovers Embodied in International Trade: Intertemporal, Regional and Sectoral Effects in a Global CGE Framework
ERM	28.2012	Claudio Morana: The Oil Price-Macroeconomy Relationship since the Mid- 1980s: A Global Perspective
CCSD	29.2012	Katie Johnson and Margaretha Breil: Conceptualizing Urban Adaptation to Climate Change Findings from an Applied Adaptation Assessment Framework

ES	30.2012	Angelo Bencivenga, Margaretha Breil, Mariaester Cassinelli, Livio Chiarullo and Annalisa Percoco: The Possibilities for the Development of Tourism in the Appennino Lucano Val d'Agri Lagonegrese National Park: A Participative Qualitative-Quantitative Approach
CCSD	31.2012	Tim Swanson and Ben Groom: Regulating Global Biodiversity: What is the Problem?
CCSD	32.2012	J. Andrew Kelly and Herman R.J. Vollebergh: Adaptive Policy Mechanisms for Transboundary Air Pollution Regulation: Reasons and Recommendations
CCSD	33.2012	Antoine Dechezleprêtre, Richard Perkins and Eric Neumayer: Regulatory Distance and the Transfer of New Environmentally Sound Technologies: Evidence from the Automobile Sector
CCSD	34.2012	Baptiste Perrissin Fabert, Patrice Dumas and Jean-Charles Hourcade: What Social Cost of Carbon? A mapping of the Climate Debate
ERM	35.2012	Ludovico Alcorta, Morgan Bazilian, Giuseppe De Simone and Ascha Pedersen: Return on Investment from Industrial Energy Efficiency: Evidence from Developing Countries
CCSD	36.2012	Stefan P. Schleicher and Angela Köppl: Scanning for Global Greenhouse Gas Emissions Reduction Targets and their Distributions
CCSD	37.2012	Sergio Currarini and Friederike Menge: Identity, Homophily and In-Group Bias
CCSD	38.2012	Dominik Karos: Coalition Formation in Generalized Apex Games
CCSD	39.2012	Xiaodong Liu, Eleonora Patacchini, Yves Zenou and Lung-Fei Lee: Criminal Networks: Who is the Key Player?
CCSD	40.2012	Nizar Allouch: On the Private Provision of Public Goods on Networks
CCSD	41.2012	Efthymios Athanasiou and Giacomo Valletta: On Sharing the Benefits of Communication
CCSD	42.2012	Jan-Peter Siedlarek: Intermediation in Networks
CCSD	43.2012	Matthew Ranson and Robert N. Stavins: Post-Durban Climate Policy Architecture Based on Linkage of Cap-and-Trade Systems
CCSD	44.2012	Valentina Bosetti and Frédéric Ghersi: Beyond GDP: Modelling Labour Supply as a 'Free Time' Trade-off in a Multiregional Optimal Growth Model
ES	45.2012	Cesare Dosi and Michele Moretto: Procurement with Unenforceable Contract Time and the Law of Liquidated Damages
CCSD	46.2012	Melania Michetti: Modelling Land Use, Land-Use Change, and Forestry in Climate Change: A Review of Major Approaches
CCSD	47.2012	Jaime de Melo: Trade in a 'Green Growth' Development Strategy Global Scale Issues and Challenges
ERM	48.2012	ZhongXiang Zhang: Why Are the Stakes So High? Misconceptions and Misunderstandings in China's Global Quest for Energy Security
CCSD	49.2012	Corrado Di Maria, Ian Lange and Edwin van der Werf: Should We Be Worried About the Green Paradox? Announcement Effects of the Acid Rain Program
CCSD	50.2012	Caterina Cruciani, Silvio Giove, Mehmet Pinar and Matteo Sostero: Constructing the FEEM Sustainability Index: A Choquet-Integral Application
CCSD	51.2012	Francesco Nicolli and Francesco Vona: The Evolution of Renewable Energy Policy in OECD Countries: Aggregate Indicators and Determinants
CCSD	52.2012	Julie Rozenberg, Céline Guivarch, Robert Lempert and Stéphane Hallegatte: Building SSPs for Climate Policy Analysis: A Scenario Elicitation Methodology to Map the Space of Possible Future Challenges to Mitigation and Adaptation
ES	53.2012	Nicola Comincioli, Laura Poddi and Sergio Vergalli: Does Corporate Social Responsibility Affect the Performance of Firms?
ES	54.2012	Lionel Page, David Savage and Benno Torgler: Variation in Risk Seeking Behavior in a Natural Experiment on Large Losses Induced by a Natural Disaster
ES	55.2012	David W. Johnston, Marco Piatti and Benno Torgler: Citation Success Over Time: Theory or Empirics?
CCSD	56.2012	Leonardo Becchetti, Stefano Castriota and Melania Michetti: The Effect of Fair Trade Affiliation on Child Schooling: Evidence from a Sample of Chilean Honey Producers
CCSD	57.2012	Roberto Ponce, Francesco Bosello and Carlo Giupponi: Integrating Water Resources into Computable General Equilibrium Models - A Survey
ES	58.2012	Paolo Cominetti, Laura Poddi and Sergio Vergalli: The Push Factors for Corporate Social Responsibility: A Probit Analysis
CCSD	59.2012	Jan Philipp Schägner, Luke Brander, Joachim Maes and Volkmar Hartje: Mapping Ecosystem Services' Values: Current Practice and Future Prospects
CCSD	60.2012	Richard Schmalensee and Robert N. Stavins: The SO2 Allowance Trading System: The Ironic History of a Grand Policy Experiment
CCSD	61.2012	Etienne Espagne, Baptiste Perrissin Fabert, Antonin Pottier, Franck Nadaud and Patrice Dumas: Disentangling the Stern/Nordhaus Controversy: Beyond the Discounting Clash
CCSD	62.2012	Baptiste Perrissin Fabert, Etienne Espagne, Antonin Pottier and Patrice Dumas: The "Doomsday" Effect in Climate Policies. Why is the Present Decade so Crucial to Tackling the Climate Challenge?
CCSD	63.2012	Ben Groom and Charles Palmer: Relaxing Constraints as a Conservation Policy
CCSD	64.2012	William A. Brock, Anastasios Xepapadeas and Athanasios N. Yannacopoulos: Optimal Agglomerations in Dynamic Economics
CCSD	65.2012	Thierry Brunelle and Patrice Dumas: Can Numerical Models Estimate Indirect Land-use Change?
ERM	66.2012	Simone Tagliapietra: The Rise of Turkey and the New Mediterranean. Challenges and Opportunities for Energy Cooperation in a Region in Transition
CCSD	67.2012	Giulia Fiorese, Michela Catenacci, Elena Verdolini and Valentina Bosetti: Advanced Biofuels: Future Perspectives from an Expert Elicitation Survey
ES	68.2012	Cristina Cattaneo: Multicultural Cities, Communication and Transportation Improvements. An Empirical Analysis for Italy

ES	69.2012	Valentina Bosetti, Cristina Cattaneo and Elena Verdolini: Migration, Cultural Diversity and Innovation: A European Perspective
ES	70.2012	David Stadelmann and Benno Torgler: Bounded Rationality and Voting Decisions Exploring a 160-Year Period
CCSD	71.2012	Thomas Longden: Deviations in Kilometres Travelled: The Impact of Different Mobility Futures on Energy Use and Climate Policy
CCSD	72.2012	Sabah Abdullah and Randall S. Rosenberger: Controlling for Biases in Primary Valuation Studies: A Meta-analysis of International Coral Reef Values
ERM	73.2012	Marcella Nicolini and Simona Porcheri: The Energy Sector in Mediterranean and MENA Countries
CCSD	74.2012	William A. Brock, Gustav Engström and Anastasios Xepapadeas: Spatial Climate-Economic Models in the Design of Optimal Climate Policies across Locations
CCSD	75.2012	Maria Berrittella and Filippo Alessandro Cimino: The Carousel Value-added Tax Fraud in the European Emission Trading System
CCSD	76.2012	Simon Dietz, Carmen Marchiori and Alessandro Tavoni: Domestic Politics and the Formation of International Environmental Agreements
ES	77.2012	Nicola Comincioli, Laura Poddi and Sergio Vergalli: Corporate Social Responsibility and Firms' Performance: A Stratigraphical Analysis
ES	78.2012	Chiara D'Alpaos, Michele Moretto, Paola Valbonesi and Sergio Vergalli: Time Overruns as Opportunistic Behavior in Public Procurement
CCSD	79.2012	Angelo Antoci, Simone Borghesi and Mauro Sodini: ETS and Technological Innovation: A Random Matching Model
CCSD	80.2012	ZhongXiang Zhang: Competitiveness and Leakage Concerns and Border Carbon Adjustments
ES	81.2012	Matthias Bürker and G. Alfredo Minerva: Civic Capital and the Size Distribution of Plants: Short-Run Dynamics and Long-Run Equilibrium
ERM	82.2012	Lion Hirth and Falko Ueckerdt: Redistribution Effects of Energy and Climate Policy: The Electricity Market
CCSD	83.2012	Steven Van Passel, Emanuele Massetti and Robert Mendelsohn: A Ricardian Analysis of the Impact of Climate Change on European Agriculture
CCSD	84.2012	Alexandros Maziotis, David S. Saal and Emmanuel Thanassoulis: Profit, Productivity and Price Performance Changes in The English and Welsh Water and Sewerage Companies
CCSD	85.2012	Alexandros Maziotis, David S. Saal and Emmanuel Thanassoulis: Output Quality and Sources of Profit Change in the English and Welsh Water and Sewerage Companies
ES	86.2012	John P. Conley, Ali Sina Önder and Benno Torgler: Are all High-Skilled Cohorts Created Equal? Unemployment, Gender, and Research Productivity
CCSD	87.2012	Fabio Farinosi, Lorenzo Carrera, Alexandros Maziotis, Jaroslav Mysiak, Fabio Eboli and Gabriele Standardi: Policy-relevant Assessment Method of Socio-economic Impacts of Floods: an Italian case study
CCSD	88.2012	Ruben Bibas and Aurélie Méjean: Bioenergy and CO2 Sequestration: Climate Policies Beyond Technological Constraints
CCSD	89.2012	Mireille Chiroleu-Assouline, Jean-Christophe Poudou and Sébastien Roussel: North / South Contractual Design through the REDD+ Scheme