North / South Contractual Design through the REDD+ Scheme

Preliminary version[*]

Mireille Chiroleu-Assouline[†] Jean-Christophe Poudou[‡]

Sébastien Roussel[§]

First version: January 30, 2012

This version: April 16, 2012

Abstract

Climate change is a worldwide issue that needs to be tackled. One of the primary source of carbon emissions is deforestation and forest degradation responsible of anthropogenic GHG emissions in a range of 12% (Van der Werf *et al.* (2009)) to 15-20% (IPCC (2007a, 2007b)). 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 design the post-Kyoto architecture. There is currently an ongoing debate with regards to the REDD+ scheme

---

[*]This paper is distributed for purposes of comment and discussion only. Please do not circulate or cite without the author's permission.

[†]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

in terms of rewards given to developing countries. The first objective of our article is to theoretically ground the REDD+ scheme as a contractual relationship in the light of the theory of incentives, either through a performance-based contract or through a conditionality-based contract. The second objective is to show that a conditional approach can be designed through actions or effective domestic efforts in developing countries towards avoided deforestation.

In our analytical framework, we get a few important results. Firstly, we can state that, like in any contract dealing with hidden information, there is an information rent / efficiency trade-off within a REDD+ scheme. If the contract is performance-based, information rents are awarded to countries with the ex ante lowest deforestation in order to incite them to induce the highest efficiency whilst coping with deforestation. A puzzling result emerges: resulting avoided deforestation through effective domestic efforts can be decreasing with the baseline announced. If the contract is conditionality-based, 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 to tackle forest areas where deforestation is *per se* the highest. Secondly, whilst comparing these contracts, there is a baseline threshold in terms of efficiency towards less deforestation.

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 responsible of anthropogenic GHG emissions in a range of 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 decade (Heal and Conrad (2006))[1]. There is an urgent need to cope with deforestation as induced climate change costs would increase to 1 Trillion US dollars (USD) at the 2100 time horizon (Eliasch (2008) cited by Lederer (2011)). Curbing deforestation is not an infeasible task as Eliasch (2008) states that 3.5 Gt CO2 could be saved per year. As a consequence, there is a need to conceive 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+)[2] scheme to design the post-Kyoto architecture. The REDD+ scheme was first 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 last December. The idea of the REDD+ scheme is rather simple and intuitive: developed countries (or Northern countries) pay developing countries (or Southern countries) to implement reduction in carbon emissions from forests whilst covering their opportunity costs to do so in altering their development path. 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 reduction of deforestation in comparison to a baseline (meaning the Business-As-Usual (BAU) deforestation level if the REDD+ scheme were not effective or rather the Reference Level (RL) allowing compensation to the developing country if emissions are below that level within the REDD+ scheme[3]) that needs to be agreed. Developed countries benefit from climate change mitigation in avoiding to take any action to cope with carbon emissions directly, in delegating the climate change mitigation task to developing countries in rewarding them.

There is currently an ongoing debate with regards to the REDD+ scheme in terms of

[1]This figure can be compared 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.

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

rewards given to developing countries. According to Karsenty and Ongolo (2011), REDD is original in the sense that this is an incentive as intrinsically it rewards States for their achievement in the action against deforestation. They underline that REDD payments are therefore performance-based and this leaves the choice of policy intruments 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. 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 (2011)). 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 Martimort (2002)). The second objective is to show that a conditional approach can be designed through actions or effective efforts towards avoided deforestation. The originality of our paper is that we design and compare two types of contracts: 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. The underlying questions within our methodological approach can be summarized as follows: How could we design complete contracts? How does incomplete information and its extent in terms of hidden information leading to adverse selection change the REDD+ scheme? How does incomplete information increase the costs of the REDD+ scheme through information rents? Asymmetric information indeed prevents policymakers from using first-best economic instruments through information rents with trade-offs between efficiency and information rents. To our best knowledge, there is no analytical paper of the REDD+ scheme in the way of the theory of incentives.

In the literature, several studies have been interested in climate change mitigation and low cost policies compared to costly abatement of fossil fuel emissions, *e.g.*, regarding carbon sequestration in agricultural soils (Chiroleu-Assouline and Roussel (2010)) or avoided deforestation (Heal and Conrad (2006), Murray *et al.* (2009), Figuières *et al.* (2010)). 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 (NGOs action, etc.), and to compensate these efforts. We keep this proposal in our theoretical framework. 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 limitation or any limitation of 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+. On our side, 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. In other words, this is a two-stage relationship between an international payment tier and a national payment tier, and between a national payment tier and land users. At the national level, they compare two types of contracts - fixed price and opportunity cost - for PES across two governments types - so-called benevolent and budget maximising. They show that a fixed price contract paying local communities on the value of the service provided by avoided deforestation is more efficient and fair. However, they do not assess any incomplete information issue in both stages. Complete contracts with hidden information and revelation principle make reference to Myerson (1979), Baron and Myerson (1982) as well as Baron (1989)[4]. Karsenty and Ongolo (2011) describe literally how the theory of incentives is at the core of the REDD+ scheme, and they request conditionalities for carbon payments. We go further in constituting the theoretical approach and reveal what is at stake in designing these contracts. In addition, our idea is to contract and use effective domestic effort observation to regulate developing countries whilst preserving forests and respect their commitment. This adapts the Laffont and Tirole's idea (1986, 1993) to use cost observation to regulate firms in industrial economics within our conditionality-based avoided

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

deforestation contract when avoided deforestation is observable.

In our analytical framework, we get a few important results. Firstly, we can state that, like in any contract with hidden information, there is an information rent / efficiency trade-off within a REDD+ scheme. If the contract is performance-based, information rents are awarded to countries with the ex ante lowest deforestation in order to incite them to induce the highest efficiency whilst coping with deforestation. A puzzling result emerges: resulting avoided deforestation through effective domestic efforts can be decreasing with the baseline announced. If the contract is conditionality-based, 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 to tackle forest areas where deforestation is per se the highest. Secondly, whilst comparing these contracts, there is a baseline threshold in terms of efficiency towards 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 scheme, whereas in Section 5, we design and analyse the conditionality-based effective domestic efforts contract that we call conditional avoided deforestation scheme. A full discussion is provided in Section 6 in terms of contract comparison regarding their efficiency towards lower deforestation, baseline assessment and political economy insights. Last, concluding remarks are offered in Section 7.

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 so far. For the sake of simplicity, we reason in terms of deforestation rate and baseline rate per year within a developing country, as well as in Millions of US Dollars (MUSD) regarding respectively the benefits of deforestation, the costs of avoiding deforestation, and monetary compensation from Northern countries to Southern countries.

The Reference Level of deforestation and compensation mechanism

Consider a developing country (say Indonesia or Guyana) who knows what deforestation rate it would expect to achieve per year as a Reference Level (RL) - baseline, *e.g.*, 0.25% per year. We suppose that this country specifies its RL through reports of private experts it has hired as consultancy. Consider a developed country as a donator (say Norway) that does not know exactly what is the rational base for computing this RL baseline. This donator country thinks that this RL baseline is of 0.25% with a probability of 1/2 but of 0.36% with a probability of 1/2. Obviously reducing deforestation implies a costly effort for the developing country who must be compensated. Hence the donator country will expect that announcing a high baseline will yield to initiatives by the developing country that will strongly moderate its deforestation. In turns, the donator country will anticipate that larger costs will have to be reimbursed and so the monetary transfer will increase with the RL baseline. Assume for simplicity that the developing country 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 baseline is 0.25%, then the domestic effort to reduce deforestation is -0.16% and costs 80MUSD[5]. Assuming that a developing country gross benefits are based on the deforestation rate achieved, for example 200MUSD in this case for a 0.09% rate[6], the developing country net benefits would be $200 - 80 = 120$MUSD here whereas they would reach 200MUSD if avoided deforestation was not effective. Hence there is a need to compensate the net loss (here 80MUSD) through a North / South monetary transfer to infer a reducing deforestation process by the developing country. This is the aim of the REDD+ mechanism which will envolve a transfer to genuinely compensate these kind of losses.

[5]Presume that the cost of avoiding deforestation (in MUSD) is $c = \frac{(RL-D).100}{2}.10$ with RL the Reference Level rate and D the Deforestation rate.

[6]Presume that the benefit of any deforestation rate per year is (in MUSD) is $u(D) = 4.(D.100)^{1/2}.10$ with D the Deforestation rate.

RL (%)	D (%)	AD (%)	T (MUSD)	RL benefits (MUSD)	Contract benefits (MUSD)
0.25	0.09	0.16	160	200	120
0.36	0.16	0.20	180	240	160

Table 1: Informed contractual proposal

If there is public information about RL, because of costly avoided deforestation and some valuable deforestation for the developing country, a complete slowing deforestation would or would not be possible. Assume that the contractual arrangement proposed by the donator would write as summarized in Table 1 (with Reference Level (RL), Deforestation (D), Avoided Deforestation (AD) and Transfer (T)).

This example features deforestation and avoided deforestation rates that are correlated to the RL baseline rate observed. For a developing country whose RL is 0.25% and effective deforestation is 0.09%, net benefits through compensation are $120 - 80 + 160 = 200$MUSD which is just equal to the RL benefit outside any contractual arrangement as the REDD+ scheme. The same stems for a 0.36% RL and an 0.16% effective deforestation rate.

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

Unobservable reducing domestic efforts

Firstly, let us consider that avoided deforestation through reducing domestic efforts is difficult to observe by the donator country implying that only consequent deforestation is observed (*ex post*). Then a developing country with a 0.25% RL that currently chooses the contract set for a developing country with a 0.36% RL will earn some rents from its private information. Indeed, having a higher effective deforestation rate of 0.16% (in lieu of 0.09%), its gross benefits will be of 160MUSD though their real applied effort will not be of -0.2% but of -0.09% ($0.16\% - 0.25\%$) which cost only 45MUSD (unlike the previous cost at 80MUSD). Hence the so-called rent (benefit) will be of 95MUSD since the net benefit of "cheating" or "mimicking a higher RL" is $160 - 45 + 180 = 295$MUSD whereas the RL real benefit should be

200MUSD. Hence the developing country whose 0.25% RL has an incentive[7] to overstate its RL rate: this has a detrimental effect on the efficiency of the contract previously proposed.

Observable reducing domestic efforts

Secondly, if we consider that domestic efforts to avoid deforestation were observable and contractable for the donator country, then a developing country whose RL is 0.36% will now choose the contract set for a developing country whose baseline is 0.25%. This means that a developing country will now choose a contract where the avoided deforestation rate is lower than what is expected and then will earn some rents from its private information. Indeed, for having a lower domestic efforts to avoid deforestation at 0.16% (in lieu of 0.2%), the cost of avoiding deforestation will remain at 80MUSD but their real benefit will be of 179MUSD in deforesting at a higher rate (unlike the previous benefit of 120MUSD). Hence the so-called rent (benefit) will be of 19MUSD since now the net benefit of "cheating" this way or "mimicking a lower RL" is $179 - 80 + 160 = 259$MUSD whereas the RL real benefit should be 240MUSD. Hence the developing country whose 0.36% RL has now an incentive[8] to understate its RL rate leading also to a detrimental effect on the contract efficiency.

Facing these uncertainties, how a donator country will manage to design a REDD+ scheme? This is exactly the aim of our analysis while any developed country can offer a menu of contracts that creates an incentive for 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).

Incentive contract in case of unobservable reducing domestic efforts

We claim that when developing countries domestic efforts to avoid deforestation are unobservable, the donator country could propose such a deforestation performance incentive contract based on *ex post* deforestation rates displayed in Table 2.

In this deforestation performance incentive contract, the effective deforestation allowed to

[7]One can check that the 0.36% rate country has not such an incentive since its net benefit is 15 5MUSD lower than the RL reward (240MUSD).

[8]Again one can check that the 0.25% rate country has not such an incentive as its net benefit is lower than the RL reward.

RL (%)	D (%)	AD (%)	T (MUSD)	Contract Benefits (MUSD)
0.25	0.09	0.16	171	120
0.36	0.195	0.165	62	177

Table 2: Deforestation performance contract

any 0.36% RL country is higher than in the initial setting (0.195% in lieu of 0.16%) implying that the induced avoided deforestation is lower (0.165% in lieu of 0.2%), whereas the monetary transfers allowed are henceforth respectively 171MUSD for a 0.25% RL country and 62MUSD for a 0.36% RL country (in lieu of respectively 160MUSD and 180MUSD). Note that in this setting, the transfers are higher at the 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 valuated at 11MUSD ($171 - 160 = 11$MUSD) incentivizing the developing country to choose its corresponding contract and to behave accordingly.

Incentive contract in case of observable reducing domestic efforts

When developing countries domestic efforts to avoid deforestation are observable, the donator country could propose such a conditional avoided deforestation incentive contract displayed in Table 3.

RL (%)	D (%)	AD (%)	T (MUSD)	Contract Benefits (MUSD)
0.25	0.1	0.15	149	126
0.36	0.16	0.2	197	160

Table 3: Conditional avoided deforestation 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 149MUSD for a 0.25% RL country and 197MUSD for a 0.36% RL country (in lieu of respectively 160MUSD and 180MUSD). Note that in this setting, the transfers are lower at the 0.25% RL and are then increasing as in the initial situation to get a higher level at the 0.36% RL. In this contract, this leaves the 0.36% RL country with an 17MUSD ($197 - 180 = 17$MUSD) information rent incentivizing the developing country to choose its corresponding contract and to behave accordingly.

This bare-bones numerical example explains exactly the rationale and what was 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 250MUSD in compensation transfer[9]. Guyana has therefore "cheated" and will probably earn some rents from its private information. Indeed, having a higher effective deforestation rate, its gross benefits will be higher though their real applied efforts will be lower and less costly. Hence there is a net benefit of "cheating" or "mimicking a higher RL" country. This depicts the relevance of our analysis and how we can enlighten possible 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 they were only two types of developing countries that a developed country would face to contract upon. We extend all these intuitions in the following sections.

3 The model

There is a bilateral relationship through 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. The A is a developing country, *e.g.*, Indonesia or Guyana[10].

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

[10] We can state that another dimension of the REDD+ scheme implementation could be analysed through the theory of incentives at a national level between a government and land-users: the government would be the P and would aim at reducing deforestation in delegating this task to the land-users that would be the

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

Implementing the REDD+ scheme requires to design 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 (2011)):

- P would like an overall reduction in deforestation (mainly tropical forests). P proposes an institutional arrangement to A a priori capable of modifying the deforestation levels, but having opportunity costs in reducing these levels. The payment to do so takes the form of a direct bilateral payment or via an international fund (where P is a stakeholder), or carbon offsets or credits that A can sell on the carbon market.
- 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 contract (take-it or leave-it offer), and if the contract is signed P covers the opportunity cost of A who alters its national policy and pay some information rents to A.

Here $\theta \in [\underline{\theta}, \bar{\theta}]$ is a type that represents the intrinsic level of deforestation, with $\underline{\theta} > 0$. It is distributed with respect to $F(\theta)$ a logconcave[11] common prior, 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 less deforesting type, and $\bar{\theta}$ is the most one. This informational variable can be

A (land-users having a trade-off between production (land-use) implying deforestation or land set aside and forest growth in the developing country, and generating opportunity costs). We leave this to the next paper.

[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.

viewed as a reduced form of the deforestation level 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[12].

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 4).

[12] In subsection 6.2 we develop a more realistic extension of the model in order to take into account the negotiated setting of the baseline.

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

The avoided deforestation a is costly for A who incurs a monetary desutility $\psi(a)$ (whilst altering the country development path) such that $\psi(0) = 0, \psi'(a) > 0$ and $\psi''(a) \geq 0$. 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 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 $u(\theta - 0) = u(\theta)$. The developed country P who offers the REDD+ mechanism derives a net surplus $W = w(d) - (1+\lambda)t$ from deforestation where $w(d)$ is her gross utility assumed strictly decreasing and concave and λ is the marginal cost of public funds for P regarding monetary transfer t towards A. All agents are risk-neutral.

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

- Deforestation performance scheme $< t, d >$: effective domestic efforts to reduce deforestation are unobservable and cannot be contracted upon, with A's gross surplus as $U = u(d(\theta)) + t(\theta) - \psi(\theta - d(\theta))$.
- Conditional avoided deforestation scheme $< t, a >$: effective domestic efforts to avoid deforestation are observable and can be included in the mechanism, with A's gross surplus as $V = u(\theta - a(\theta)) + t(\theta) - \psi(a(\theta))$.

As a benchmark and to fix ideas, let us consider what would be the first-best REDD+ mechanism for which information on the baseline proxy θ is common knowledge. Effective efforts are observable and both Deforestation performance based and Conditional avoided deforestation based schemes are equivalent. In such a setting, the Principal P can costlessly extract all the A's net surplus (so U or V are set up to $u(\theta)$) and enforce any avoided deforestation $a(\theta)$ which yields to a deforestation level $d = \theta - a(\theta)$ that maximizes $W = w(\theta - a(\theta)) - (1+\lambda)(u(\theta) + \psi(a(\theta)) - u(\theta - a(\theta)))$.[16] As a result, the first best avoided

[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 domectic effort $a^* = 0$.

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

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 $d^{FB}(\theta) = \theta - a^{FB}(\theta)$.[17] At the social optimum, avoided deforestation efforts are balancing off the P's marginal cost associated to the deforestation level d, *i.e.*, $w'(d)$, and the A's marginal cost or benefit associated to 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[18] of W in a and θ (resp. in d and θ) then $a^{FB}(\theta)$ is an increasing function of θ (so is $d^{FB}(\theta)$).[19] 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 informational 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.

Lemma 1 *The first best REDD+ mechanism tends to be manipulated by developing countries. 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 those caveats. We consider successively those second best settings in the following sections.

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

[18] 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 shows that $a^{FB\prime}(\theta) = \frac{w''(\theta - a^{FB}(\theta)) + (1+\lambda)u''(\theta - a^{FB}(\theta))}{w''(\theta - a^{FB}(\theta)) + (1+\lambda)(u''(\theta - a^{FB}(\theta)) - \psi''(a^{FB}(\theta))} \in]0,1[$.

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

4 Deforestation performance scheme

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

P offers a menu of contracts to A (take-it or leave-it offer) and the timing of the game is summarized in Figure 1.

Insert Figure 1

For a given baseline $\hat{\theta}$ reported to P by A, 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 lean on the revelation principle (Myerson (1979)) that ensures that direct mechanisms are sufficient to allow that agents 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 Contraints (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

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

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

that is the marginal information rent, and thus rents are not increasing with θ. This incentives contraints are in line with the result in lemma 1: to tackle overstatement incentives included in deforestation performance schemes, the principal will give an informational rent to low deforesting countries. As a result, the developing country net rent must decrease with baseline announcement.

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

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

Hence expected rents are given by (after by parts integration)

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

Local second order incentives imply[20] that

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

To give correct incentives to the developing country, deforestation allowed is increasing with the baseline.

The expected net surplus of P writes

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

Substituting $t(\theta)$ and including expected rents leads to write his decision program as

$$\begin{aligned} \max_{d} \int_{\underline{\theta}}^{\bar{\theta}} & \{w(d(\theta)) - (1+\lambda)[u(\theta) - u(d(\theta)) + \psi(\theta - d(\theta))] \\ & -(1+\lambda)[(\psi'(\theta - d(\theta)) + u'(\theta))]\, \varphi(\theta)\}\, f(\theta)\, d\theta - (1+\lambda)U(\bar{\theta}) \end{aligned}$$

$$\text{s.t.} \begin{cases} U(\bar{\theta}) \geq 0 \\ IC2 : d'(\theta) \geq 0 \end{cases}$$

where λ is the shadow price of public funds in the developed country. From the following

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

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:

- $w'(d)$ is P's marginal cost associated to the deforestation level d. An increase (respectively decrease) in d at the margin leads to reduce (resp. enhance) P's gross utility.
- $(1+\lambda)\left[u'(d) + \psi'(\theta - d)\right]$ is A's marginal cost or benefit associated to the deforestation level d. An increase (respectively decrease) in d at the margin leads to enhance (resp. reduce) A's gross utility.
- $(1+\lambda)\psi''(\theta - d)\varphi(\theta)$ is the marginal information cost due to asymmetric information borne by P and increasing the cost of the REDD+ policy.

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

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

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 informational rent left to the most deforesting country.*

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

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

Regarding our results, we can state that 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 promote deforestation levels, the optimal scheme implies to tackle 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, whereas leaving other countries going towards a higher deforestation level. A last result is worth being noticed: resulting avoided deforestation through effective domestic efforts can be decreasing with the baseline announced. Again this is due to asymmetric information: if the informational cost $\varphi(\theta)$ increases highly as baselines are announced higher, it could be optimal to design a deforestation scheme, at least for some high types, that yields to less reducing efforts.

Another question is how the deforestation performance scheme depicted in Proposition 2 can be implemented. Using an equivalent of the taxation principle (Guesnerie (1981, 1995), Hammond (1979) and Rochet (1986)), saying that 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 through a decreasing contracts. 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[21], as the corresponding effort a is not unambiguously increasing. So it is not absolutely sure that it can be decentralized as linear contracts. Following Leplay *et al.* (2011), one could imagine to implement the REDD+ mechanism as a non linear contract $T(d) = pE(d)(\theta - d)$ where p is the international carbon (marked-based or exogenous) price and $E(d)$ is the proxy carbon emissions factor, which converts deforestation into carbon emissions.

5 Conditional avoided deforestation scheme

This REDD+ mechanism is now built in such a way that when a country A announces a baseline $\hat{\theta}$ then P is expecting that A must realize 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 (2011)). We use here avoided deforestation observation as cost observation (Laffont and Tirole (1986, 1993)) to regulate developing countries whilst preserving forests and respect their commitment.

P offers a menu of contracts to A (take-it or leave-it offer) and the timing of the game is summarized in Figure 2.

Insert Figure 2

For a given baseline $\hat{\theta}$ reported to P by A, 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))

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

[21]Indeed $T'(d) = t_d'^*(\theta)\,\theta^{*\prime}(d) = -\left[u'(d) + \psi'(\theta - d)\right] < 0$ and $T''(d) = -u''(d) - \psi''(\theta - d)\left[\theta^{*\prime}(d) - 1\right]$ has not a constant sign.

Incentive Compatibility Contraints (ICC) state that for all $\theta, \hat{\theta}$ (see Appendix 8.4 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. This incentives contraint is also in line with the result in lemma 1: to tackle understatement incentives included in conditional avoided deforestation schemes, the principal will give an informational rent to high deforsting countries. As a result, the developing country net rent must increase with baseline announcement.

Information rent is for any θ

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

and expected rents are given by (after by parts integration)

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

Local second order incentives imply[22] that

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

Avoided deforestation through effective efforts are increasing with the baseline.

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

The expected net surplus of P writes

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

Substituting $t(\theta)$ and including expected rents leads to write his decision program as

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

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

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

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

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

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

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

- $(1+\lambda)u''(\theta-a(\theta))\bar{\varphi}\left(\theta\right)$ is the marginal information cost due to asymmetric information borne by P and increasing the cost of the REDD+ policy.

The optimal transfer $t_{a}^{*}\left(\theta\right)$ 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 8.5 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 informational rent left to the less 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* $d(\theta) = \theta - a^*(\theta)$ *is not unambiguously increasing with* θ*. It decreases with* θ *if* $\bar{\varphi}(\theta)$ *is highly decreasing.*

Regarding our results, we can state that there is an information rent / efficiency trade-off in the REDD+ conditional avoided deforestation scheme that does play 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 to tackle 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 incite them to induce the highest effort $a\left(\bar{\theta}\right)$ and therefore efficiency to cope with deforestation, whilst leaving other countries going towards a higher deforestation.

6 Discussion

6.1 Contract choice, avoided deforestation and welfare

In this sub-section, we assess the effectiveness of both contracts and we compare these contracts in terms of welfare gains and losses. We realize our comparisons in a simple quadratic setting (See Appendix 8.6) comparing the contract variable, their effectiveness (in the sense that deforestation is reduced more importantly) and give the welfare analysis. 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 choosen to get interiors solutions to all outcomes and we assume also that $\lambda \leq \frac{1}{2}$. Just to fix ideas, 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. *It exists a baseline threshold $\tilde{\theta}$ such that:*

   - *if $\theta < \tilde{\theta}$, that is for low deforesting countries, deforestation performance schemes are more effective than conditional avoided deforestation schemes.*
   - *if $\theta > \tilde{\theta}$: for high deforesting countries, conditional avoided deforestation schemes are more effective than deforestation performance schemes.*

2. *It exists a baseline threshold locus $\theta^* (\Lambda)$ decreasing in Λ such that the difference between the welfare obtained through deforestation performance scheme and the welfare resulting from the conditional deforestation reducing effort scheme is positive if $\theta \geq \theta^* (\Lambda)$ and negative otherwise. Moreover $\theta^* (0) < \tilde{\theta}$.*

3. *Conditional deforestation reducing effort schemes are preferred to deforestation performance schemes since expected welfare levels are higher.*

The sign of the difference between the welfare obtained through deforestation performance scheme and the welfare resulting from the conditional deforestation reducing effort scheme depends on the level of the marginal cost of public funds in the North country in a complex way (See Appendix 8.5).

6.2 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.* (2010) 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 even "fragile" countries are ready to invest in some falsification strategies of forest core information (Karsenty and Ongolo (2011)). Following Maggi and Rodriguez (1995), assume that a prior stage can take place between the P and the A, in order to decide what would be the baseline entering in the REDD+ scheme so that now *ex-post* deforestation level d is defined as $d(b, a) = b - a$ where b is the deforestation baseline 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 RL deforestation level, $\theta \in \Theta$ observed whose realization is observed before signing the contract, within the negotiation meeting, the principal 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 baseline signalled, in either direction. The cost of falsification associated α is $\phi(\alpha)$, a convex function. With $\alpha = b - \theta$, the agent'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 case of deforestation performance schemes, incentive compatibility 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 baseline falsification. Incentives are clearly impacted by the falsification abilities consequently optimal schemes are expected to be modified because of the cost of desinformation. Rents are now not unambiguously monotonically decreasing 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 donator to propose a same contract for a set of countries with different RL levels.

6.3 Political economy regarding States

The REDD+ scheme is for the time being not encroaching on Nations sovereignty (Streck (2010)) and our analysis shows that conditionality for avoided deforestation is feasible and should be promoted. This rejoins and grounds the points of view of Combes-Motel *et al.* (2009) and Karsenty and Ongolo (2011). Nevertheless, one may stress that the national implementation of the REDD+ scheme depends on the country status whilst opposing “Solid” *versus* “Fragile” or “Failed” States (Karsenty and Ongolo (2011)). “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 unability to reach commitments in international agreements on natural resource management (Irland (2008)). Corruption is latent in these States and as a consequence conditionalities have to ground the REDD+ scheme rather than performance, and local projects through Payments for Environmental Services (PES) have to be enhanced with direct relationships between developed countries and local population and NGOs. This local level of application would be suitable in these States even though first projects are experiencing corruption, nepotism and pressure on local population (Lederer (2011)). Moreover, a disintermediation of current players in the tropical timber market has to be supported in order to protect forests, to increase population standard of leaving and to alleviate poverty (Heal and Conrad (2006)).

As a result, we can assert that:

- Conditionality is a principle that needs to be at the core of the REDD+ scheme design towards developing countries to avoid deforestation, and we have shown that conditional avoided deforestation contracts are feasible and suitable when avoided deforestation is observable;
- States have to be assessed by the international community to propose the most suitable way to implement the REDD+ scheme:
  - Either by bilateral relationships between developed countries and developing countries, and then conditional national implementation for "Solid" States;
  - Or, directly through PES programs between developed countries and local populations and NGOs within developing countries through PES projects for "Fragile" or "Failed" States.

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 for avoided deforestation. Incomplete information as hidden information creates information rents on developing countries side that renders the REDD+ policy more costly and involves trade-off between the struggle over deforestation and informational rents left to the developing countries. One of our main result is that limiting deforestation and forest degradation should be incentive-based whilst controlling effective domestic efforts in developing countries. However discussion arises with regards to the political stability of the developing countries involved in REDD+ schemes.

Another dimension of the REDD+ scheme would be biodiversity conservation. One of the extensions of our paper will be to include biodiversity as a co-benefit of less deforestation and forest degradation. In the theory of incentives way of analysis, the aim of a developed country (as the Principal) would be twofold, to reduce deforestation to mitigate climate change and to increase biodiversity or watershed conservation, whilst delegating this task to a developing country (the Agent). Nevertheless, there might be a trade-off between avoided deforestation and biodiversity conservation if low deforestation opportunity costs correspond to high biodiversity conservation potentials (Matta *et al.* (2009), Ring *et al.* (2010)).

Last, several methodological aspects have to be solved for an effective REDD+ implementation and to allow conditionality: permanence of any achieved storage have to be ensured; there is a need for Monitoring, Reporting and Verification (MRV) systems to increase capacity building; 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.

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 $d(\hat{\theta}) > d(\theta)$: $d()$ 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 informational rent left to the most deforesting country 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 Global Incentive Compatibility Constraint (ICC) with the conditional avoided deforestation scheme

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

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

add up and 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.

8.5 Optimal contract 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 informational rent left to the less deforesting country 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 $\bar{\varphi}(\bar{\theta}) = 0$).

- $a^*(\theta)$ 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

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

8.6 Contract comparison in a specific setting

Consider that baseline types are distributed upon the support $[1, 2]$ according to an 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 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 $\lambda \leq \frac{1}{2}$; consequent 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 $\tilde{\theta} = \frac{5}{3} : d^*\left(\tilde{\theta}\right) = \hat{d}^*\left(\tilde{\theta}\right)$ 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 settings, *i.e.*, first-best Scheme, deforestation performance scheme, conditional avoided deforestation scheme respectively: the deforestation evolvement $d(\theta)$ (Figure 3), the avoided deforestation evolvement $a(\theta)$ (Figure 4) and the transfer evolvement $t(\theta)$ (Figure 5)

Insert Figures 3, 4 and 5

[θ on the X axis;

red: First-Best Scheme (FBS), black = Deforestation Performance Scheme (DPS),

and blue = Conditional Avoided Deforestation Scheme (CADS) on the Y axis]

Let us compute the first-best welfare and the second-best welfare for each scheme and each type, respectively deforestation performance and conditional avoided deforestation 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[23] $\theta^*(\Lambda) = \frac{11-6\,\Lambda-2\sqrt{153\,\Lambda^2-90\Lambda+7}}{3(4\,\Lambda+1)}$ which is in Θ for $\Lambda \geq \frac{2}{3}$. 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 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 $E\left(\Delta W(\theta)\right) = \frac{2\Lambda-5}{9(2\,\Lambda+1)\Lambda}$ which is negative for admissible values of Λ.

References

[1] Baron D. P., 1989. Design of Regulatory Mechanisms and Institutions. in R. Schmalensee and R.D. Willig eds. The Handbook of Industrial Organization. Elsevier North-Holland.

[2] Baron D. P. and Myerson R.B., 1982. Regulating a Monopolist with Unknown Costs. *Econometrica*. 50, 911-930.

[3] 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.

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

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

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

[7] Figuières C., Leplay S., Midler E. and Thoyer S., 2010. The REDD Scheme to curb Deforestation: a well-designed System of Incentives? *Working Papers, LAMETA*. 2010.06.

[8] Guesnerie R. (1981), On Taxation and Incentives; Further Remarks on the Limits to Redistribution, Bonn Discussion Paper 89.

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

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

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

[12] 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.

[13] 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.

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

[15] Karsenty A. and Ongolo S., 2011. 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*. In Press.

[16] 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.

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

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

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

[20] Lederer M., 2011. From CDM to REDD+ — What do we know for setting up effective and legitimate carbon governance? *Ecological Economics*. 70, 1900-1907.

[21] 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.

[22] Maggi G. and Rodriguez-Clare A., 1995. Costly distortion of information in agency problems, *RAND Journal of Economics*, 26(4), 675-689.

[23] Matta R.J., Alavalapati J.R.R. and Mercer D.E., 2009. Incentives for Biodiversity Conservation beyond the Best Management Practices: are Forestland Owners Interested? *Land Economics*. 85(1), 132-143.

[24] 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.

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

[26] Ring I., Dreschler M., van Teeffelen A.J.A., Irawan S. and Venter O., 2010. Biodiversity Conservation and Climate Mitigation: what Role can Economic Instruments Play? *Current Opinion in Environmental Sustainability*. 2, 50-58.

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

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

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

[30] 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.

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

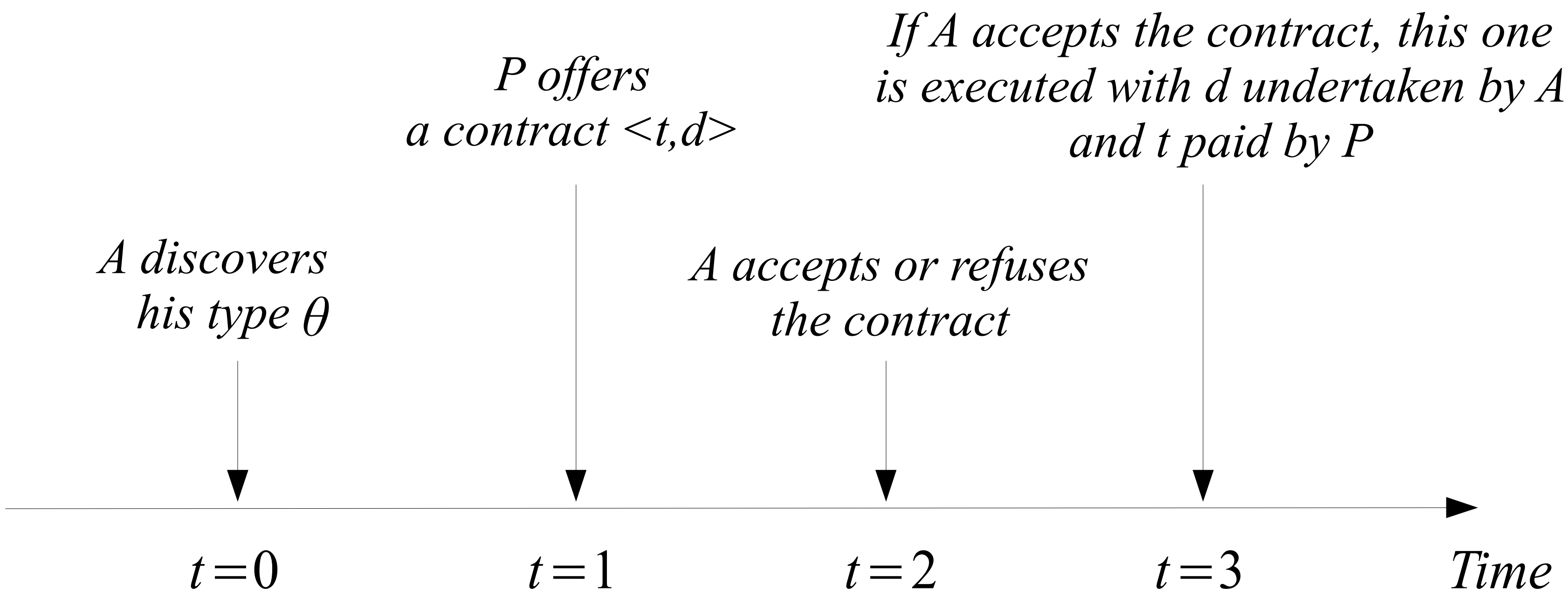


Figure 1. Contracting timing in the deforestation performance scheme

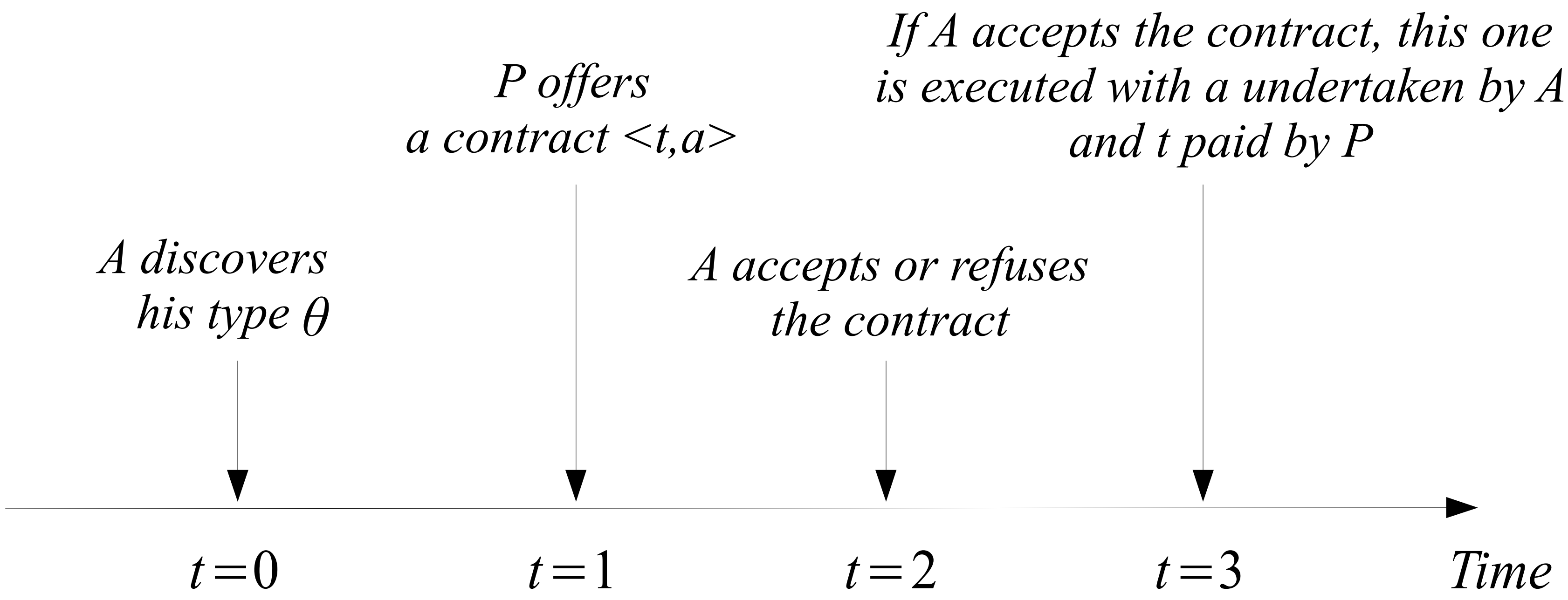
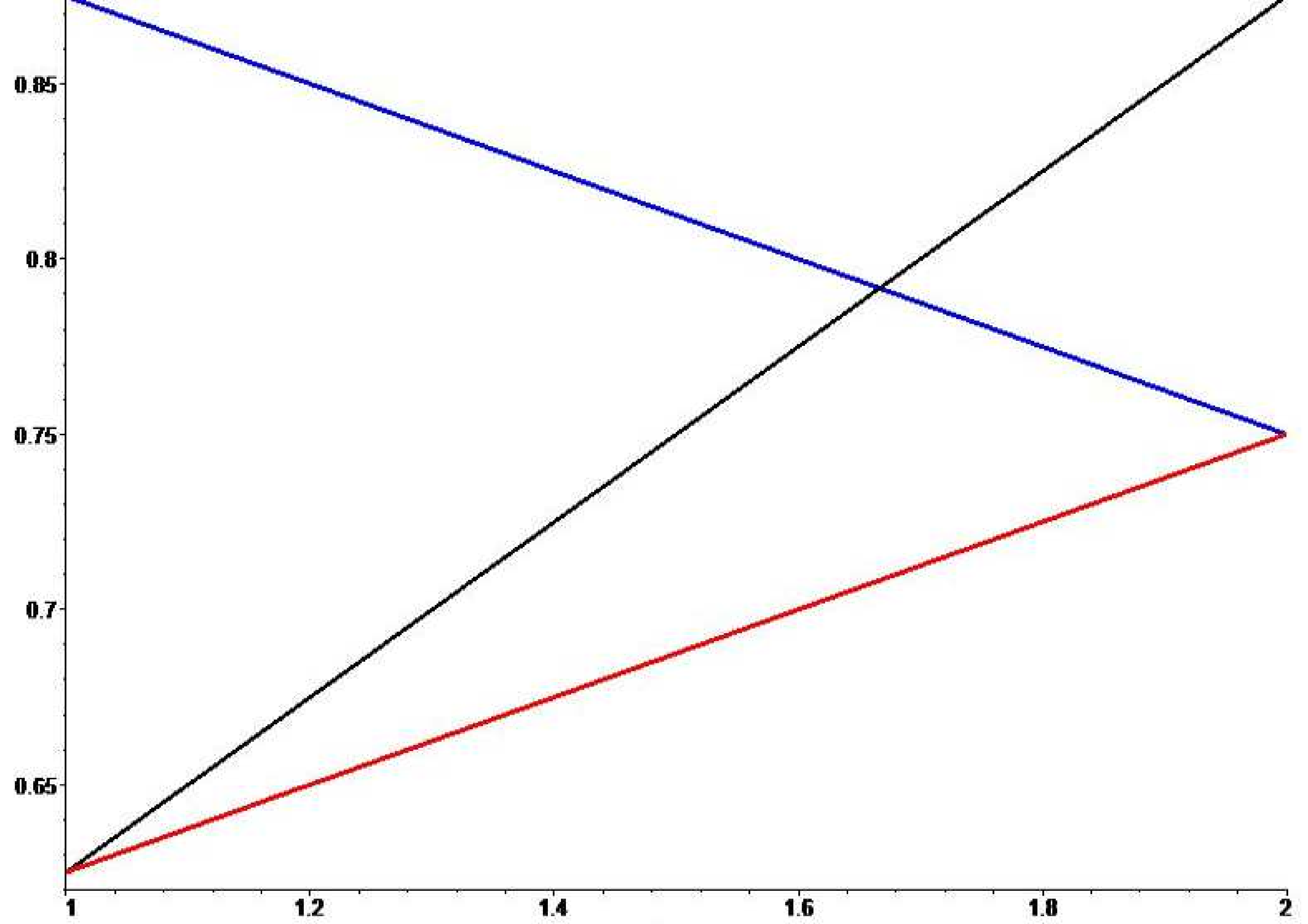
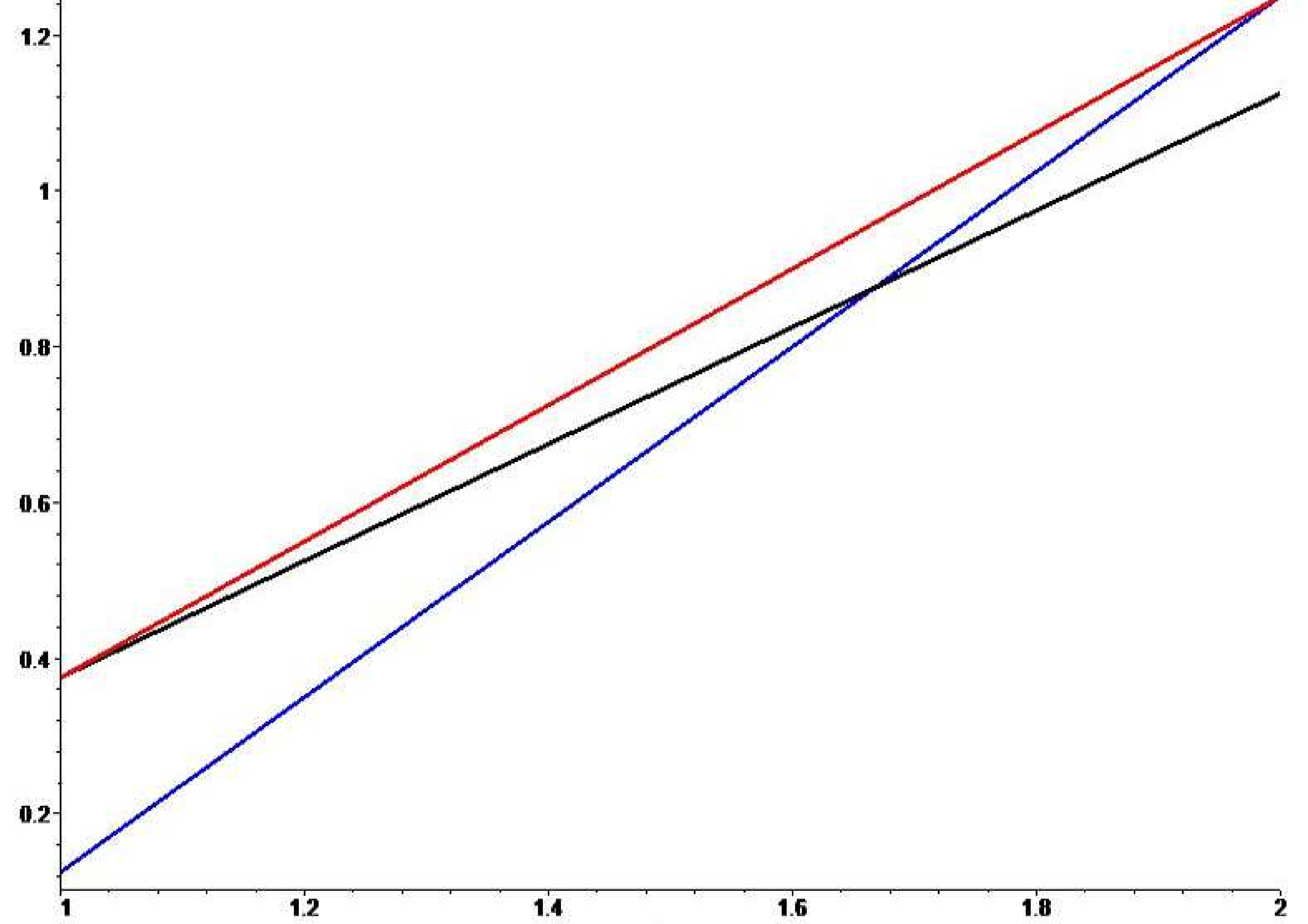
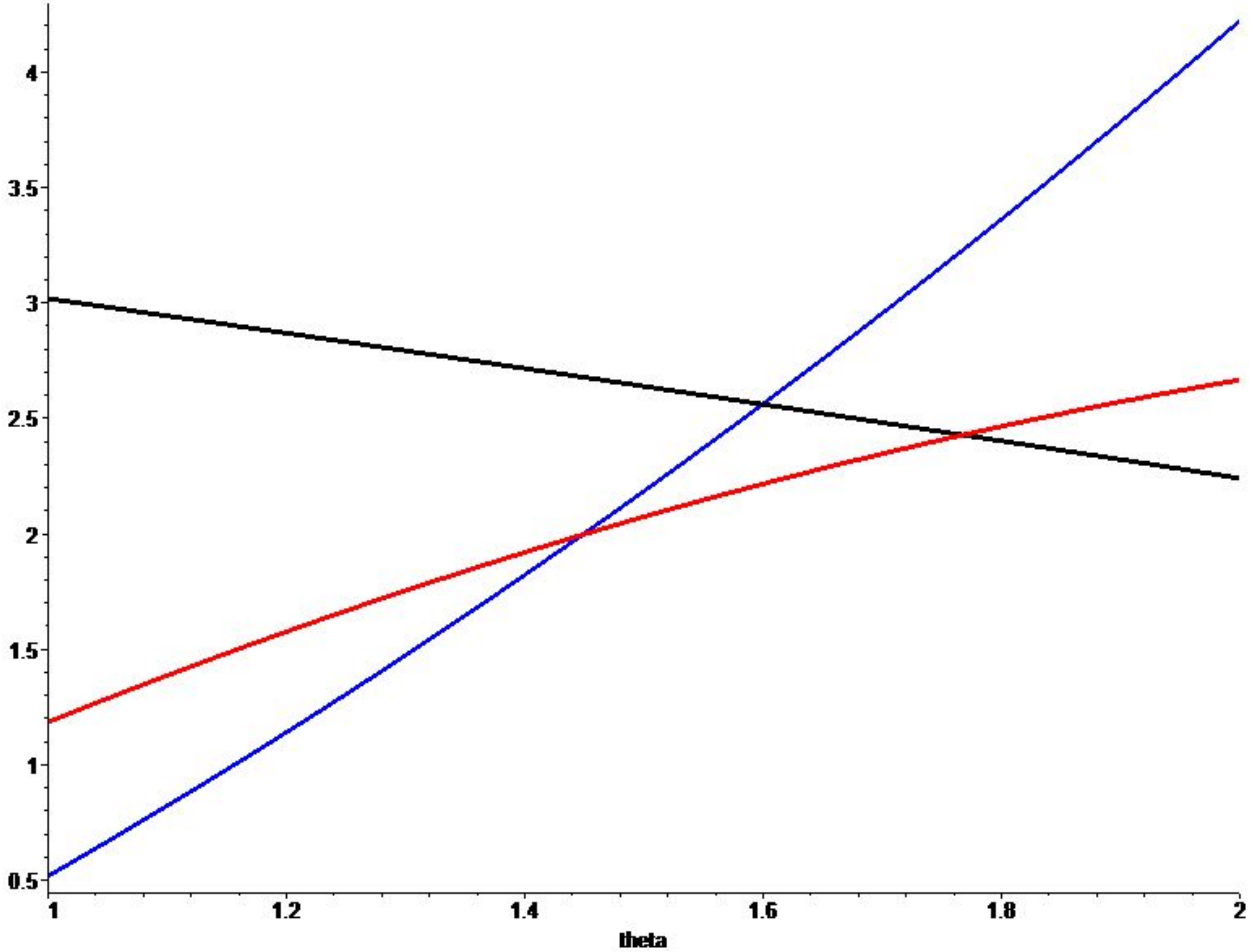


Figure 2. Contracting timing in the conditional avoided deforestation scheme


0.85
0.8
0.75
0.7
0.65
1
1.2
1.4
1.6
1.8
2



1.2
1
0.8
0.6
0.4
0.2
1
1.2
1.4
1.6
1.8
2



4
3.5
3
2.5
2
1.5
1
0.5
1
1.2
1.4
1.6
1.8
2
theta