How do location and certification impact additionality of REDD+ projects? Theory and Evidence

Philippe Delacote [*][†][‡], Gwenole Le Velly [§][¶], Gabriela Simonet [‖][**]

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Abstract

How is location of REDD+ projects chosen, and how do those location choices influence project additionality? This paper assesses these questions, presenting a simple theoretical model and using an original database of REDD+ projects in Brazil. We show that project location is strongly influenced by the type of project proponent, which appears to be a good proxy for its objectives, whether oriented toward environmental impacts, development impacts, or external funding. Our results suggest that the incentives behind REDD+ certification mechanisms can lead to low environmental effort or an investment in areas that are not additional.

Keywords: Deforestation, REDD+, Additionality, Spatial analysis.

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[*] INRA, AgroParisTech, Laboratory of Forest Economics, Nancy, France

[†] Climate Economics Chair, Paris, France

[‡] Corresponding author: philippe.delacote@inra.fr

[§] LAMETA, Montpellier SupAgro, CNRS, INRA, Univ. Montpellier, Univ. Paul Valéry, Montpellier, France

[¶] Corresponding author: gwenole.le-velly@supagro.fr

[‖] LAMETA, INRA, CNRS, Montpellier SupAgro, Univ. Montpellier, Univ. Paul Valéry, Montpellier, France

[**] Center for International Forestry Research, Bogor, Indonesia

1 Introduction

REDD+ is an international initiative aimed at compensating developing countries for their participation in the global effort of climate change mitigation through their reductions of deforestation and forest degradation, as well as the conservation and enhancement of their forest carbon stocks.

At the local level, REDD+ has resulted in hundreds of REDD+ projects. Some of these projects are financed through the sale of carbon credits, which are supposed to remunerate their additionality. The additionality of forest conservation projects can be defined as the avoided deforestation attributable to the project (**??**). It is based on a comparison between the actual deforestation in the area under conservation and an hypothetical counterfactual situation of no project implementation. As explained by **?**, additionality is determined by the share of area enrolled that would not meet program requirement, for instance forest conservation, without program implementation.

In this article, we explore the interactions between the type of project proponents, the choice of a location, the type of certification scheme and the additionality of REDD+ projects. Our theoretical results shows that project proponents face a trade-offs between targeting additional areas and efficient allocation of scarce resources. In some cases, given the uncertainty of carbon credit certification, it can be optimal for the project proponent to implement a project in a location that generates very low additionality in order to maximise funds from the carbon markets. Moreover, the theoretical model also shows that pursuing conjointly social and environmental objectives might lead to lower additionality.

We test these hypotheses by estimating empirically the additionality of 9 REDD+ projects located in the Brazilian Amazon. We consider two types of actors: Non-Governmental Organisations (NGOs) and private-for-profit organisations; and two types of standards for certification: the Voluntary Carbon Standard (VCS), which focuses on the carbon dimension of the projects, and the Climate, Communities and Biodiversity (CCB) Alliance standard, which addresses the non-carbon impacts of the projects. Our empirical analysis confirms the theoretical predictions of the model. As a matter of fact, proponents that rely less on the carbon markets for funding, here NGOs compared to private-for-profit organizations, tends to implement more additional projects. Moreover, projects using only the VCS certification appear to be more additional than those combining two certification schemes.

In the second section, the REDD+ mechanism and the different certification standards are presented. Section 3 develops a theoretical model that combines the type of projects proponents, the choice of a location and the choice of a certification scheme, and derives conclusion for the additionality of projects. In the fourth section, our theoretical insights are tested, using an original database obtained through georeferencing of 9 REDD+ projects in Brazil. We empirically study both the determinants of the location choice according to the type of project proponents and the certification scheme, and the additionality of each type of projects. To estimate additionality, we rely on impact evaluation methodologies as recommended in the recent literature about forest conservation policy instruments (???). Section five concludes and makes recommendations for the implementation of REDD+ projects.

2 Context

2.1 The REDD+ mechanism

Annual emissions from tropical deforestation and degradation are estimated at around 7-14 percent of global carbon dioxide (CO2) emissions (???), making tropical forests a key issue for global climate change mitigation. Over the last two decades, tropical forests gradually became a central element of the the United Nations Framework Convention on Climate Change (UNFCCC) strategy for climate change mitigation. Afforestation and reforestation projects were included in the Clean Development Mechanism (CDM) of the Kyoto Protocol signed in 1997 and a mechanism aimed at Reducing Emissions from Deforestation and forest Degradation, known as RED, was established during the 11th Conference of the Parties (COP) that took place in Montreal in 2005. The core idea of this mechanism was to offer financial rewards to developing countries in exchange for emissions reductions achieved through decreased deforestation. The mechanism was later expanded to include provisions addressing forest degradation, along with conservation, the sustainable management of forests, and the enhancement of forest carbon stocks, and renamed REDD+ accordingly. The Paris Agreement, which entered into force in November 2016, recognizes the role of forests as carbon sinks and emphasizes, in its Article 5, the necessity for implementing REDD+. Article 4 of the Paris Agreement requires that UNFCCC Parties prepare Nationally Determined Contributions (NDCs) that detail their national mitigation strategy to contribute to the global objective of keeping global temperature rise below 2.0-1.5 degree Celsius above pre-industrial levels. A majority of tropical countries has included forestry, land use, and land-use change in their NDCs (?).

Although REDD+ was initially proposed as a national mechanism, pilot activities were encouraged during COP 13 in Bali (?). As of September 2016, over 300 REDD+ projects are being implemented across the tropics (?). Among the various sources of funding used by REDD+ projects proponents, 69 percent of the projects plan to sell carbon credits (?). The forest carbon credits generated by REDD+ projects are well represented in the voluntary carbon markets. Indeed, in 2015, REDD+ projects (including tree-planting and improved forest management) generated 18 percent (or 15 megatons of CO2 equivalent) of the total volume of offsets transacted in this market (**?**).

Among REDD+ countries, Brazil is the country with the highest number of REDD+ projects, with 41 projects implemented as of 2014 (**?**). Brazil is a key player in the field of deforestation, because deforestation generates 44 percent of the total greenhouse gases emissions of the country (in 2012, according to data from the World Resource Institute) and because of the significant shift observed in the Brazilian deforestation since 2004. Indeed, the annual deforestation rate in Brazil fell by 70 percent between 2005 and 2013 due to the implementation of command-and-control measures, the expansion of protected areas, and interventions in the soy and beef supply chains, such as the Soy Moratorium established in 2006 (**?**). In 2009, Brazil received about one billion of USD to implement REDD+ projects, mainly by Norway, through the Amazon Fund. This fund makes Brazil the main recipient of REDD+ funding (**?**).

Since its creation in 2005, the REDD+ mechanism has generated much academic debate. On the one hand, REDD+ has been presented as a promising tool, capable of channeling substantial funding to forest conservation, notably through carbon markets, and of delivering multiple benefits, by combining climate change mitigation, biodiversity conservation and poverty alleviation. On the other hand, REDD+ has raised considerable criticism, in particular as regards its environmental and social impacts. The environmental effectiveness of the mechanism has been questioned for several reasons. First, the risk of leakage has been highlighted, which refers to the fact that forest carbon emissions avoided by REDD+ programs or projects can create or increase CO2 emissions outside the territory covered by REDD+ activities (**???**). Second, forest carbon projects are subject to a risk of non-permanence, which corresponds to the risk of reversibility of the emissions reductions achieved by a project (**?**). Finally, the additionality of REDD+ projects, which corresponds to the environmental benefits that would not have happened without a project, has also been questioned, notably due to the difficulty in establishing accurate baseline scenarios of future deforestation (**?**). In addition to these environmental issues, concern has been expressed by many academics and organizations defending human rights about the potential negative social impacts of REDD+ (**?**), which is feared to generate, among others, tenure conflicts, displacements of people for conservation reasons or 'green-grabbing', which is defined as the "the appropriation of land and resources for environmental ends" (**?**).

2.2 Certification standards

To prevent the potential negative environmental and social impacts of REDD+, the UNFCCC Cancun Agreement established seven safeguards (Decision 1, CP.16). In the voluntary carbon markets, although there is no legal authority which controls and certifies carbon credits, several certification schemes emerged as an answer to the fear expressed by buyers that REDD+ carbon credits could be associated with non-permanence, lack of additionality or negative social impacts (**?**). In 2014, half of REDD+ projects were certified by one of the standards of the voluntary market (**?**). Data provided by **?** indicates that 40 percent of REDD+ projects certified or in the process of certification are using the VCS, which is the most commonly used of the voluntary market standards (**?**). The VCS validates carbon monitoring methodologies proposed by project proponents and applies the same methodological principles as the CDM. Project proponents seeking VCS certification must submit a Project Design Document (PDD) that describes the methodology used to estimate the emissions reductions or carbon sequestration generated by the project, as well as the strategy used to deal with the risks of non-permanence, leakage and non-additionality. The VCS dealt with the risk of non-permanence by the creation of a reserve of carbon credits, also called 'buffer', which represents between 10 to 40 percent of the total quantity of carbon credits, depending on the estimated risk of non-permanence of each project (**?**). The use of a buffer represents an innovation compared to the CDM, where the risk of non-permanence was addressed by the creation of 'temporary credits', which participated in the low attractiveness of CDM forestry credits, due to the complexity of their use. An assessment of each project against VCS rules by an independent third partiy, know as Validation and Verification Body (VVB), is necessary before the project proponent can sell carbon credits.

To answer buyers concern regarding the potential negative impacts of REDD+ projects on biodiversity or local people, projects proponents often combine the VCS certification with a certification by the Climate, Community and Biodiversity (CCB) Alliance standard, which focuses on the non-carbon benefits of the projects. **?** reports than three-quarters of the VCS forestry credits transacted in 2014 were also certified by the CCB.

Under the umbrella of REDD+ projects, a vast heterogeneity of projects can be found, notably in terms of project type, location, proponents or funding sources (**?**). Given this heterogeneity among projects, it seems crucial when questioning the additionality of REDD+ projects to wonder, not only if REDD+ projects generate additionality, but which types of projects generate additionality.

Some authors already highlighted the link between the national REDD+ strategy and the type of REDD+ projects implemented in a country, and its position on the forest transition curve (**??**). Other showed that the location of REDD+ projects can be explained by the presence of protected areas (**?**), as well as the baseline CO2 emissions, the forest carbon stock, the number of threatened species, the quality of governance and the region, with a bias toward Latin America (**?**).

Other less explored sources of heterogeneity are the type of project proponent and the certification scheme adopted. Regarding project proponents, the large majority of REDD+ projects is implemented by the private sector, either by non-for-profit organizations such as NGOs that see REDD+ projects as a new source of financing for forest conservation projects, or by for-profit carbon companies that seek to start capital-generating projects focused on carbon. Public sector and research institutes represent less than 20 percent of the proponents (**?**). The certification process is also very heterogeneous as some certification addresses only carbon issues and others consider the social and biodiversity impacts of the projects.

In the rest of the paper, we focus on projects of avoided deforestation, which represent around half of the REDD+ projects worldwide (**?**).

3 Modelling additionality and location selection

A project proponent (Pp) aims to set an avoided deforestation project, with a set of various objectives: avoided deforestation, livelihood improvement, and income from the project. For that purpose, three choices have to be made: (1) first, a certification scheme m; (2) a project location i; (3) an effort allocation e.

We proceed backward: We first consider the business-as-usual scenario of deforestation and livelihoods levels, as well as the community response to the REDD+ project. Second, we consider how the Pp allocates his effort between the avoided deforestation and livelihood objectives. Third, the choices of location and certification schemes are considered.

3.1 Buisiness-as-usual cases

We consider a set of $N \in [1, ..., n]$ potential REDD+ projects locations. Each location i is represented by a benefit b_i for each unit of deforestation d_i. v is the cost of deforestation, including non-market benefits from forest conservation. We assume convex costs, with a quadratic specification. The representative agent in location i thus maximizes livelihoods:

$$\max_{d_i} u_i = b_i d_i - \frac{v}{2} d_i^2 \tag{1}$$

Under no intervention, the optimal level of deforestation is thus: $\overline{d_i} = \frac{b_i}{v}$. The level of livelihoods is: $\overline{u_i} = \frac{b_i^2}{2v}$. Those levels are considered as the business-as-usual scenarios.

3.2 REDD+ project

The project proponent has three kinds of objectives: (1) a weight α is given to the outcome in terms of avoided deforestation (which is our indicator of additionality); (2) a weight β is given to the livelihood quality of the community where the project is implemented; (3) a weight $(1-\alpha-\beta)$ is given to financial aspects, approximated by the amount of money received from selling REDD+ credit on voluntary carbon markets.

The project proponent first selects one location among the N possible ones, as well as a certification scheme. He then chooses his effort allocation between environment (avoided deforestation) and development (improving livelihoods). Indeed, the outcome of the project is twofold: a level of deforestation and a level of livelihoods. We proceed backward.

3.3 Community's reaction to the REDD+ project

The Pp allocates his effort between reducing deforestation (e) and improving livelihood in the community $(1-e)$. We consider that effort allocated to environmental objectives increases the benefit from forest conservation for the community, and that effort allocated to livelihoods improvement increases the net benefit from the community's activities.

Moreover, depending on the selected project, effort may be more effective for environmental purpose than for development purpose, or vice versa. Thus effort efficiency is $\delta_i e$. For $\delta_i > 1$ (resp. < 1), effort is more (less) productive for environmental purpose than development ones. Further more, effort efficiency is likely to depend on the marginal benefit from deforestation: $\delta_i(b_i)$. Indeed, opportunity costs from avoided deforestation are larger when the marginal benefit of deforestation is larger, which decreases the effort efficiency for avoided deforestation. On the contrary, larger marginal benefits may represent larger development potential, and thus larger effort efficiency in terms of livelihood improvement. Thus we can consider that $\delta_i'(b_i) < 0$. [1]

The representative agent's utility thus becomes:

$$\max_{d_i} u_i = (2-\delta_i e)(b_i d_i - \frac{v}{2}((1+\delta_i e)d_i)^2) \tag{2}$$

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[1] For the simulations, we consider that $\delta_i(b_i) = 1/b_i^a$.

The community's reaction to the REDD+ project is thus:

$$\begin{aligned} d_i^*(e) &= \frac{b_i}{v}\frac{1}{(1+\delta_i e)^2} && (3)\\ u_i^*(e) &= \frac{b_i^2}{2v}\frac{(2-\delta_i e)}{(1+\delta_i e)^2} && (4)\end{aligned}$$

The community reacts to the effort allocation in the following way:

$$\begin{aligned} d'_{ie} = \frac{\partial d_i^*(e)}{\partial e} &= \frac{b_i}{v}\frac{-2\delta_i}{(1+\delta_i e)^3} < 0 && (5)\\ u'_{ie} = \frac{\partial u_i^*(e)}{\partial e} &= \frac{b_i^2}{2v}\frac{\delta_i(\delta_i e - 5)}{(1+\delta_i e)^3} < 0 \iff \delta_i < 5/e && (6)\end{aligned}$$

Avoided deforestation from the project is:

$$AD_i(e) = \overline{d_i} - d_i^*(e) = \frac{b_i}{v}\frac{\delta_i e(2+\delta_i e)}{(1+\delta_i e)^2} \tag{7}$$

Avoided deforestation is increasing in e:

$$AD'_{ie} = \frac{\partial AD_i^*(e)}{\partial e} = \frac{b_i}{v}\frac{2\delta_i(1-\delta_i e)}{(1+\delta_i e)^2} > 0 \iff \delta_i < 1/e \tag{8}$$

Livelihoods improvement from the project is:

$$\begin{aligned} \Delta_i(e) &= u_i^*(e) - \overline{u_i} = \frac{b_i^2}{2v}\frac{(1-\delta_i^2 e^2 - 3\delta_i e)}{(1+\delta_i e)^2} && (9)\\ \Delta'_{ie} &= \frac{b_i^2}{2v}\frac{\delta_i(\delta_i e - 5)}{(1+\delta_i e)^3} < 0 \iff \delta_i < 5/e && (10)\end{aligned}$$

For the remaining of the paper, we will focus on the case of low enough environmental effort efficiency: $\delta_i < 1$.

3.4 A simple model of effort allocation in a REDD+ project

3.4.1 Optimal effort allocation

As noticed before, the project proponent has three kinds of objectives: avoiding deforestation, improving livelihoods and increasing income from the REDD+ project. The objective of the Pp is thus to allocate his effort in order to maximize its utility from the project, taking location i and certification m as given:

$$\max_e v_{im}(e) = \alpha U_E(AD_i(e)) + \beta U_L(\Delta_i(e)) + (1-\alpha-\beta)U_F((p_{cm}(\gamma_{cm}\overline{d_i} - d_i^*(e)) + p_{um}(u_i^*(e) - \gamma_{um}\overline{u_i}))) \tag{11}$$

We consider that utility from environmental improvement (U_E), utility from livelihood improvement (U_L) and utility from project funding (U_F) are all increasing and concave.[2]

$AD_i(e)$ is the actual level of avoided deforestation (supposedly known by the Pp). $\Delta_i(e)$ is the project impacts in terms of livelihood improvement. $p_{cm}(\gamma_{cm}\overline{d_i} - d_i^*(e))$ is the amount of money received from selling REDD+ credits on voluntary markets under certification m. p_{cm} is the price of carbon credits, while γ_{cm} is the level of stringency relating avoided deforestation to credits. A low (< 1) γ_{cm} represents strong requirements and/or low uncertainty in baseline estimation, while a large (> 1) γ_{cm} represents low levels of stringency and/or high uncertainty regarding the baseline. $p_{um}(u_i^*(e) - \gamma_{um}\overline{u_i})$ represents the payment related to livelihoods improvement under certification m. p_{um} is the price premium that may be paid to the project proponent if such co-benefit is taken into account by the certification scheme[3]. γ_{um} is the stringency level of livelihood improvement measurements. If $\gamma_{um} < 1$, the initial level of livelihoods is underestimated, which tends to overestimate livelihoods improvements. Thus the label is considered loose in terms of livelihoods measurements. In contrast, it is considered stringent if $\gamma_{um} > 1$.

Overall, the certification scheme m is composed of 4 elements: a carbon price p_{cm}, a level of environmental stringency γ_{cm}, a price premium to livelihood improvement p_{um} and a level of livelihoods stringency γ_{um}.

The first-order condition implicitly gives the effort allocation e^* of the Pp:

$$v'_{um}(e) = \alpha U'_E(AD'_{ie}) + \beta U'_L(\Delta'_{ie}) + (1 - \alpha - \beta)U'_F(-p_{cm}d'_{ie} + p_{um}u'_{ie}) = 0 \tag{12}$$

The optimal allocation effort e^* is chosen so that the marginal environmental benefit of increasing effort on forest preservation equals the marginal economic benefit of increasing effort on livelihood improvement.

3.4.2 What drives effort allocation?

In order to analyze what drives effort allocation for the project proponent, we will consider several cases. First, we consider what happens when the project proponent is not interested in funding from certifying his project : the *NoMo* case. Project proponents are all interested in obtaining funding since they all asked for certification. However, we study this extreme to analyse the decisions made by the proponents less interested by funding. Second, we will focus on a project

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[2] Log functions will be used for the simulations.

[3] If the certification scheme only considers the avoided deforestation output, with no importance given to livelihoods as a co-benefit, we simply have $p_{um} = 0$.

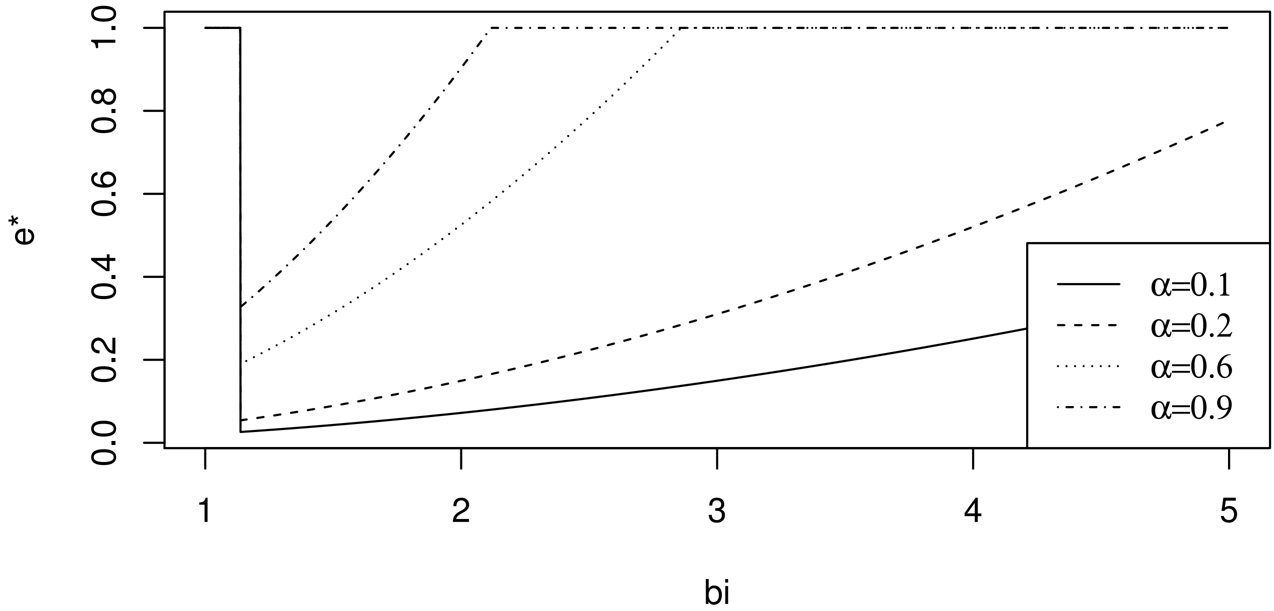
proponent only interested in funding from carbon markets: the *OnMo* case. Finally, we will consider the interaction between funding and the other two objectives: *BoMo* case.

NoMo Case: $(\alpha + \beta = 1)$.

When the project proponent does not consider external funding in its objective function, the effort allocation e^* is increasing in α and decreasing in β. Moreover, the optimal effort allocation is increasing in b_i: the marginal effort efficiency is increasing in b_i for both environmental and development purposes ($\frac{\partial AD'_{ie}}{\partial b_i} > 0$ and $\frac{\partial \Delta'_{ie}}{\partial b_i} < 0$). Finally, the optimal effort is decreasing in δ_i (as $\frac{\partial AD'_{ie}}{\partial \delta_i} < 0$ and $\frac{\partial \Delta'_{ie}}{\partial \delta_i} > 0$).

Result 1 : *When the project proponent does not focus on external funding from carbon markets, his environmental effort allocation* e^* *increases in environmental preferences* α*, decreases in livelihood preferences* β*, increases in the community marginal benefit* b_i *and increases in environmental effort efficiency* δ_i*. If the environmental effort efficiency is decreasing in the marginal benefit from deforestation, then effort may be either increasing or decreasing in* b_i*.*

Figure 1: Effort allocation for diverse values of b_i, α, *NoMo case*



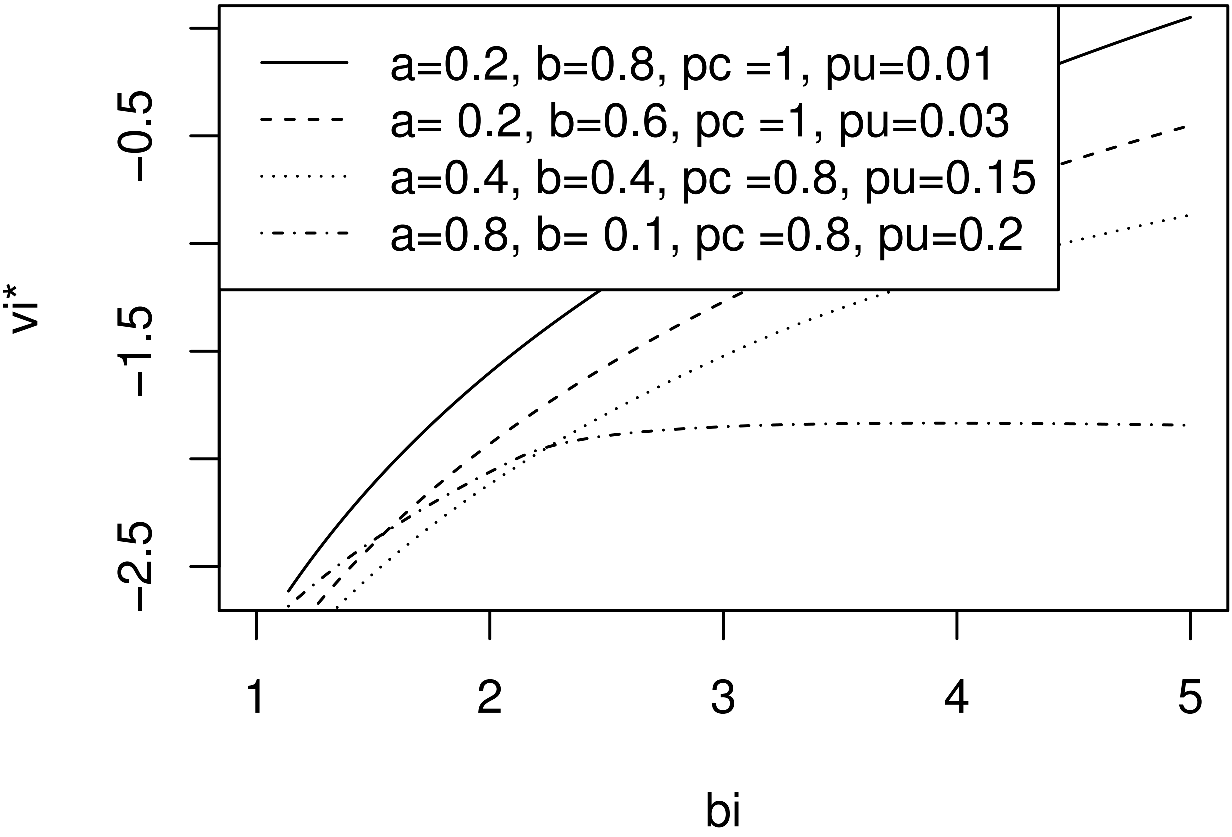
OnMo Case: $(\alpha + \beta = 0)$.

If the project proponent only cares about funding from carbon markets, his effort will be entirely focused on environmental purposes or development purposes. We have the following corner solution:

$$\begin{cases} e^* = 0 \iff p_{um}u'_{ie} > p_{cm}d'_{ie} \\ e^* = 1 \iff p_{um}u'_{ie} < p_{cm}d'_{ie} \end{cases}$$

Result 2 : *When the project proponent only focuses on external certification funding, his environmental effort allocation* e^* *will be maximal if the price given to avoided deforestation* p_c *is high enough, if the price given to livelihood improvement* p_u *is low enough, if the environmental effort efficiency* δ_i *is high enough, if the marginal benefit from avoided deforestation* b_i *is high enough. It will be null in the contrary.*

Figure 2: Project value for various levels of b_i, p_c, p_u, *OnMo case*



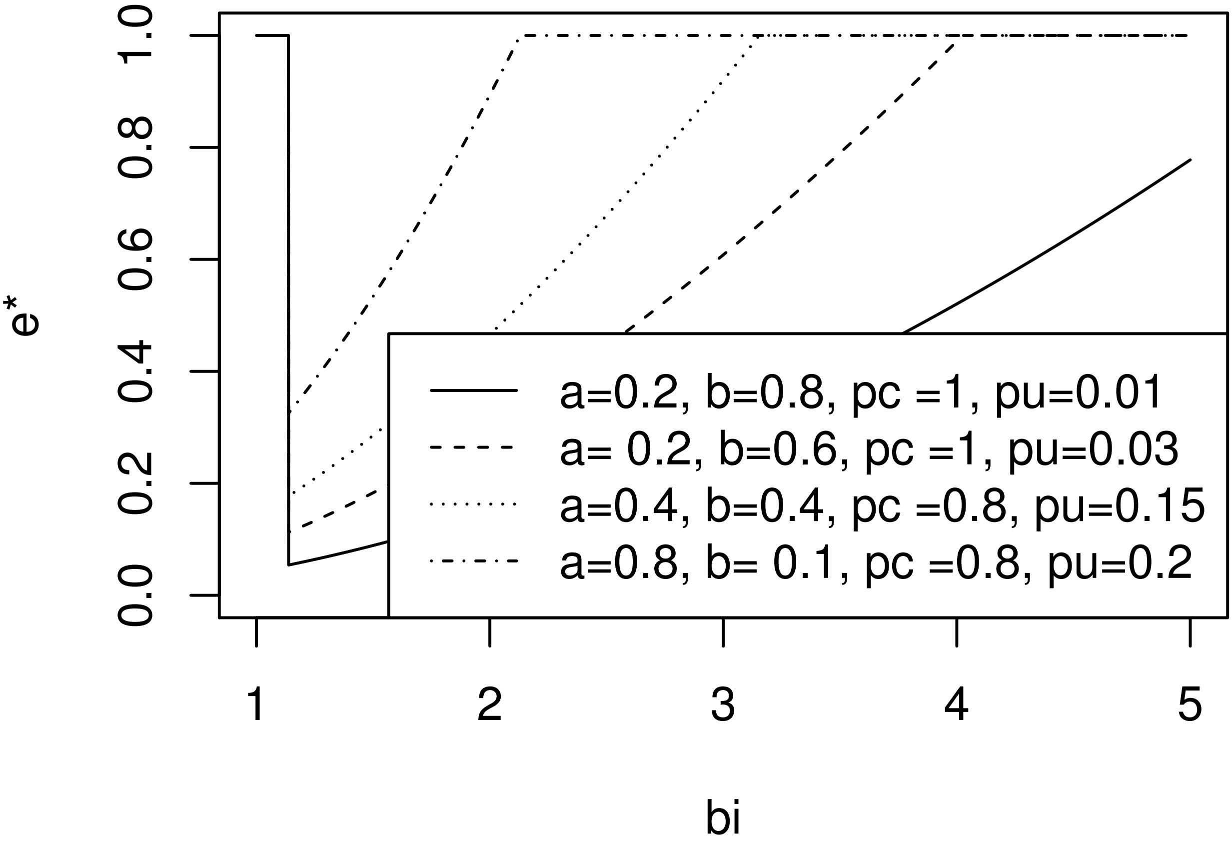
BoMo Case: $(0 < \alpha + \beta < 1)$.

When the project proponent cares both about projects impacts and certification funding, this tends to put an extra-weight on avoided deforestation or livelihoods. This extra-weight depends on the condition:

$$\begin{cases} \frac{\partial e^*}{\partial \alpha} < 0 \; and \; \frac{\partial e^*}{\partial \beta} > 0 \iff p_{um} u'_{ie} > p_{cm} d'_{ie} \\ \frac{\partial e^*}{\partial \alpha} < 0 \; and \; \frac{\partial e^*}{\partial \beta} < 0 \iff p_{um} u'_{ie} < p_{cm} d'_{ie} \end{cases}$$

Result 3: *When the project proponent considers both impacts from the project and certification funding, increasing the importance given to avoided deforestation (resp. livelihoods) increases (decreases) environmental effort if the price given to avoided deforestation* p_c *is high enough, if the price given to livelihood improvement* p_u *is low enough, if the environmental effort efficiency* δ_i *is high enough, if the marginal benefit* b_i *is high enough. It will be decreasing (increasing) in the contrary.*

Figure 3: Effort allocation for diverse values of b_i, α, β, p_c, p_u, *BoMo case*



3.5 Choosing project location

At first, the Pp has to select the right location for implementing the REDD+ project. Locations are represented by the couples levels of marginal benefit from deforestation and potential project efficiency: $L(b_i, \delta_i)$. It is important to note here that the project impacts not only depend on the effort repartition described in the previous period, but also on the initial conditions in the project location.

Overall, as shown before, the optimal effort level depends on the two variables that define location: $e^*(b_i, \delta_i(b_i))$. Thus the choice of the project location is linked to the selection of the right b_i.

The project location is chosen so that:

$$\begin{aligned} \max_{b_i} v_i(e^*(b_i, \delta_i(b_i))) &= \alpha U_E(AD_i(e^*(b_i, \delta_i(b_i)))) + \beta U_L(\Delta_i(e^*(b_i, \delta_i(b_i)))) \\ &+ (1-\alpha-\beta) U_F(p_c(\gamma_c \overline{d_i} - d_i^*(e^*(b_i, \delta_i(b_i)))) + p_u(u_i^*(e^*(b_i, \delta_i(b_i))) - \gamma_u \overline{u_i})) \end{aligned} \tag{13}$$

Location i is chosen if the following condition is satisfied:

$$v'_{um}(b_i) = (e^{*'}_{b_i} + e^{*'}_{\delta_i} \delta'_i(b_i)) v'_{um}(e) + (1-\alpha-\beta)(p_c \gamma_c \overline{d}'_{ib_i} - p_u \gamma_u \overline{u}'_{ib_i}) = 0 \tag{14}$$

Therefore, when choosing the project location, the project proponent considers how location will affect his effort allocation, through two channels: the marginal benefit from deforestation and the effort efficiency. Larger marginal benefit b_i tends to increase the potential livelihood benefit from the project, but it also decreases the effort efficiency in terms of avoided deforestation. Finally, larger b_i tend to increase financial aspects from credits.

If we consider first the simple case where the environmental effort efficiency does not depend on the marginal benefit from deforestation, it is trivial to see that both avoided deforestation and livelihood improvement increase with b_i. Thus, in this case, the project proponent will choose the location with the highest marginal benefit from deforestation, whatever his preferences in terms of environmental and livelihoods benefits.

Yet, due to higher opportunity costs of avoided deforestation, the marginal benefit from deforestation is likely to have a large impact on environmental effort efficiency. In this case, larger environmental preferences may push the project proponent to select a location with lower marginal benefit from deforestation.

Result 4: *If the marginal benefit has low impact on the environmental effort efficiency (δ_i close to 1, whatever b_i), then the project proponent will tend to choose a location with large marginal ben-*

efit whatever his preferences in terms of avoided deforestation, livelihoods, or certification funding. If the marginal benefit has a large effect on the environmental effort efficiency ($\frac{\partial \delta_i}{\partial b_i} < 0$ *and large enough), the project proponent will choose a lower* b_i *if* α *increases, and a larger* b_i *if* β *increases.*

Figure 4: Project value for diverse values of b_i, α, *NoMo case*

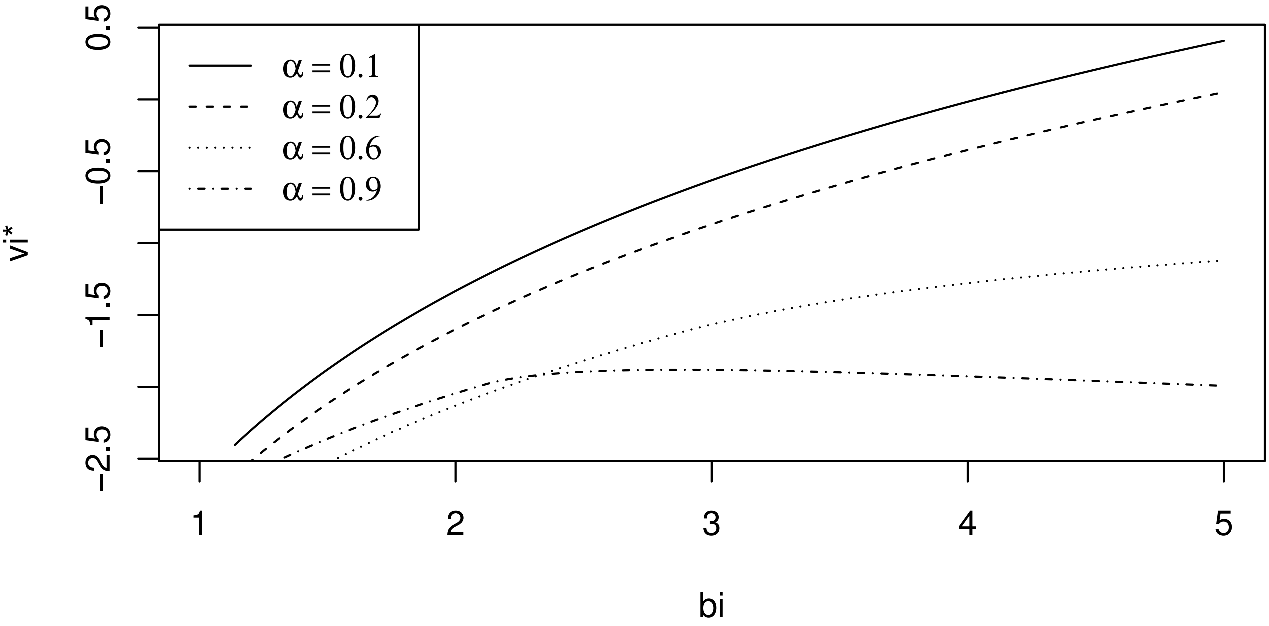
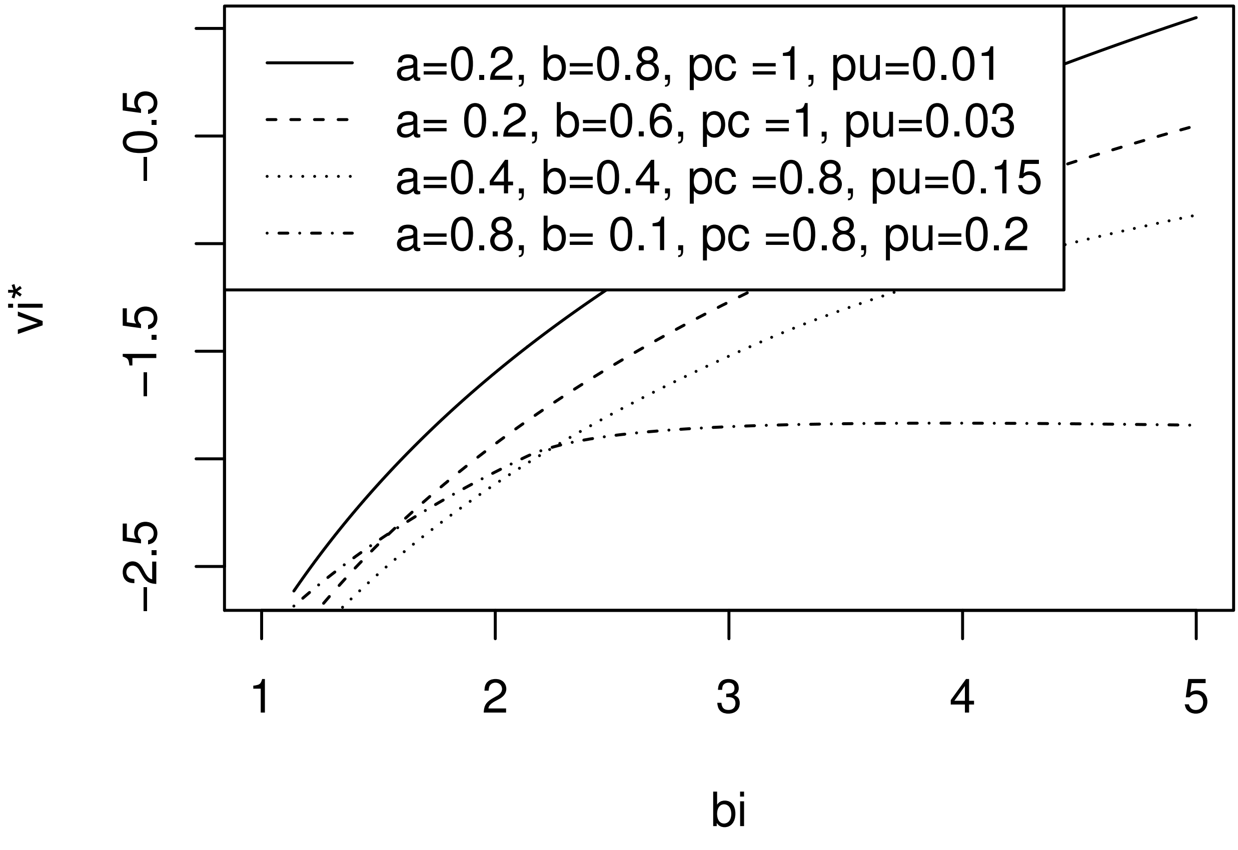


Figure 5: Project value for diverse values of b_i, α, β, p_c, p_u, *BoMo case*



3.6 Choosing the certification scheme

Finally, the Pp has to select the certification scheme m that best fits with his objectives, within the M possible certification schemes. A certification scheme is a combination of credit prices, requirement levels and certification cost k: $C(p_c, \gamma_c, p_u, \gamma_u, k)$. The chosen certification scheme will be the one maximizing:

$$\max_{m\in[0,\dots,M]} v_{im}(e^*) = (p_c(\gamma_c\overline{d_i} - d_i^*(e^*)) + p_u(u_i^*(e^*) - \gamma_u\overline{u_i})) - k \tag{15}$$

Location i is chosen if the following condition is satisfied:

$$v_{im}(e^*) > v_{is}(e^*),\ \forall\ s \neq m \tag{16}$$

Result 5: *Project proponents will tend to choose the certification scheme associated to the highest possible price, and the lowest possible additionality requirement.*

3.7 Testable Hypotheses

According to the results of our theoretical model, the objectives of the project proponents influence his choice of a location, defined by a marginal benefit b_i and an environmental effort efficiency $\delta_i(b_i)$, his environmental effort e and the certification scheme. We also show that interactions between b_i and $\delta_i(b_i)$ influence the environmental effort.

We can hypothesize that b_i strongly and negatively influences the environmental effort efficiency $\delta_i(b_i)$. In this case, we can show that the Pp will provide lower environmental effort (Result 1 and 2). This is especially the case when the Pp is only motivated by funding from carbon markets ($\alpha = 0$ and $\beta = 0$): this case converges towards a corner solution where his environmental effort e_i is null. Note that, if the level of environmental stringency of the carbon standard is low (γ_{cm}>1) i.e. if the baseline of deforestation is overestimated, the Pp can still get funding from carbon markets even if his environmental effort is null.

Moreover, from Result 5, we understand that the choice of certification is related the the weight given to environmental (α) and social preferences (β) in the objective function of the Pp. Therefore, we can hypothesize that the Pp that chooses a double certification have higher social preferences than that Pp that only obtained VCS certification. In this case, Result 4 suggests that Pp with higher β will favor locations with higher b_i even though the environmental efficiency will be low which, according to Result 1, lead to a low additionality.

By combining Results 1, 2, 4 and 5, we can focus on two testable hypotheses:

- A Pp only motivated by funding from carbon markets favors areas with lower (or null) opportunity costs and generates less additionality.

- A Pp that chooses a double certification favor areas with high opportunity costs but generates less additionality.

4 Empirical analysis

4.1 Data

? built an international database of REDD+ projects around the world. This database is available online[4] and contains 454 projects located in 56 countries. As of May 2017, the database included information about 57 projects in Brazil, of which 31 are ongoing projects of avoided deforestation (REDD). However, a vast majority of these projects were not certified. Given the scope of this article, we focus on projects that relied, or will soon rely, on funds coming from the voluntary carbon markets. Therefore, we choose to focus on projects that already obtained the VCS and/or the CCB certifications. Moreover, we choose to focus on conservation projects (REDD) instead of reforestation ones for two reasons. First, it is easier to monitor deforestation than reforestation using satellite images. Second, reforestation projects are smaller, making georeferencing complicated if not impossible.

Our sample is composed of 9 REDD projects that cover around 2 millions hectares of forests. We georeference each project using the Project Design Documents (PDD) that the proponents of the projects must elaborate in order to obtain the certification. The projects that are promoted by private-for-profit organizations tend to rely more financially on the voluntary market. In line with our theoretical model, the income obtained from the projects is a strong objective for these actors compared to NGOs. Qualitative evidence collected during the construction of the ID-RECCO database showed us that NGOs rely only partially on the carbon market. As a matter of fact, most NGOs already existed and had their source of funding before selling carbon credits while many private-for-profit organisations merged for the purpose of selling carbon credits. This hypothesis is supported by the fact that, according to the database, selling carbon credits appear as an objective of the project in around 50% of the REDD projects proposed by private for profit organisations against 36% for NGOs.

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[4] `http://www.reddprojectsdatabase.org/`

Table 1: List of projects

Certification	Actors	Variable	Number of projects
VCS only	Private for-profit	$VCS^{Pri} = 1$ / $Type_i = 1$	3
CCB and VCS	Private for-profit	$CCB^{Pri} = 1$ / $Type_i = 2$	3
CCB and VCS	NGO's	$CCB^{Ngos} = 1$ / $Type_i = 3$	3

Our sample of projects is composed of three groups, further detailed in Table **??**. All the projects obtained VCS certification but only six of them obtained CCB certification. The three projects that did not obtain CCB certification are implemented by private for-profit proponents. Three projects are implemented by NGOs and they all obtained both CCB and VCS certifications.

The PDDs include a map of the projects in PDF format that can be projected using a GIS software but lacks of geographic coordinates. In order to locate each project, we use shape files mapping waters, urban areas and roads, provided online by the *Instituto Brasileiro de Geografia e Estatística* (IBGE) and Digital Chart of the World, and the shape file of protected areas provided by the International Union for Conservation of Nature (IUCN). We overlap each image extracted from the PDD with some of these geographic features to locate the 9 projects. Once the project are located, we draw the polygons that correspond to each project. We use this methodology for the 9 REDD projects. We build polygons that measure on average 108% of the project areas declared by project proponents. This ratio is heterogeneous but for 8 projects out of 9, the difference between computed and declared areas is lower than 15% (33% for the last one).

In order to estimate the impact of the project on deforestation, we use deforestation data provided by PRODES[5]. PRODES is a national program that provides geographic data about deforestation and forest cover in the Legal Amazon between 2006 and 2014, based on LandSat images of 20 to 30 meter resolution. Except for one project, the georeferenced projects all started during this period of analysis. As we will explain in the next section, this progressive entry into the REDD+ mechanism allows us to estimate the impact of the program using panel estimations. The starting dates of the REDD+ projects are detailed in Table **??**.

In order to build a database, we use a similar procedure as **?**, combining conservation policies, gridding and forest cover. We use a gridding of 5km x 5km so that each cell measures 2,500 hectares. We intersect this grid with the forest cover in 2005 at the beginning of our period

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[5] http://www.dpi.inpe.br/prodesdigital/prodes.php

Table 2: Starting date of the projects

Starting year	2002	2006	2007	2008	2009	2011	2012
Number of projects	1	1	1	1	3	1	1

analysis using PRODES data and create a new shape file of forested cells. All non forested areas in 2005 are excluded from our sample. Eventually, we intersect this shape file with the REDD projects and protected areas boundaries. Therefore, each forested cell is either entirely within or outside protected areas and/or REDD projects. This procedure allows us to compute yearly deforestation between 2006 and 2014 within each cell. We drop cells of less than 1000 hectares as they mainly result from mis-overlap and may bias our results.

4.2 Methods

4.2.1 Choice of a location

In the first stage of our analysis, we study the choice of a location by project proponents according to the type of certification and the type of proponents. In Section **??**, we defined three groups of projects. In order to study the difference in the choice of location for each type of REDD+ projects proponents, we restrict our sample to the cells included in one of the 9 REDD projects. We obtain a sample of 859 observations.

Given the small number of REDD projects, we can not claim to identify the impact of the characteristics of a location on the probability of enrolment in one type of project or another. For this reason, we rely on qualitative evidence based on difference-in-mean tests. We study the characteristics of the locations using variables influencing the opportunity costs of deforestation. We believe that these variables are strong determinants of b_i in the theoretical model. Higher b_i are associated with higher opportunity costs and those areas are likely to be more additional. Moreover, higher b_i can decrease the environmental efficiency $\delta_i(b_i)$ of the environmental effort e_i.

We focus on six variables: the distance to the nearest road, the distance to the nearest location, the distance to the Amazon frontier that we approximate by the distance to the border of the Eastern States of Mato Grosso and Para, distance to the first non-forest point, slope in percent rise and the number of hectares of deforestation in the neighbouring cell in 2006 (the first year of analysis). All distances are in hundreds of kilometers.

Since there are three types of projects we compute three pairwise tests in order to compare the samples two by two. For each test, we analyse if the characteristics of the location chosen by one type of Pp differ from the one chosen by the two other types type of Pp separately.

$$H0 : \bar{X_i} - \bar{X_j} = 0$$

$$H1 : \bar{X_i} - \bar{X_j} \neq 0$$

4.2.2 Additionality

In the second stage of analysis, we estimate the additionality of each type of projects according to the categories specified in Table **??**. Additionality can not be estimated only by comparing enrolled and non enrolled areas. As a matter of fact, there are factors, called confounding variables, influencing both deforestation and the enrolment in a REDD+ projects, making simple comparisons irrelevant. To estimate the additionality, we rely on impact evaluation methodologies and combine matching methods with panel estimations. In line with this literature, we define the areas enrolled in the REDD projects as treated areas and build a counterfactual using a control group of non-enrolled areas.

In order to build a relevant counterfactual, we use a pre-matching procedure for each REDD projects (**?**). The objectives of this procedure is to select a group of observations that are as similar as possible to the treated areas and only differs regarding the treatment. For each REDD project, we consider as treated the cells that are located within the polygon of the project. We define our control group as all the cells located within a distance of 20 to 150km (or 200 km for the largest project) around each project.

In order to obtain a valid estimation of the impact, the Stable Unit of Treatment Value Assumption (SUTVA) must hold. This hypothesis requires that the outcome of an observation, here deforestation, is only influenced by its own status regarding the treatment. In our case, it means that the project does not impact deforestation in the control group. For this reason, we consider that the direct buffer of 20km around the projects (approx. the four closest cells from the project) is likely to be influenced by the project through leakage for instance (**?**). If we do not exclude the neighboring cells, the SUTVA hypothesis would not hold and the estimation might be biased. However, in order to identify the impact of the projects, the choice of the control and treated groups must take into account unobservable confounding factors that affect both deforestation and the location of the REDD projects. By restricting our control group to the cells that are located no further than 150km from the REDD project, we hope to balance unobservable covariates such as agro-ecological conditions. We also exclude protected areas and/or other REDD+ projects from the control group since they also are under conservation policies.

For each project, we use a propensity score matching procedure without replacement. For each cell located within a REDD projects, we select the nearest neighbor in terms of propensity score. For each project, we estimate the following model:

$$Pr(REDD_i = 1) = \eta + \sum_{l=1}^{9} \rho_l X_{li} + \nu_i \tag{17}$$

X_{li} is a vector of L variables including geographic characteristics that are structural determinants of deforestation (**???**) such as distances to the closest waters, roads and localities, the distance to the Amazon frontier that we approximate by the distance to the border of the Eastern States of Mato Grosso and Para, distance to the first non-forest point, slope in percent rise, elevation in meters and the number of hectares of deforestation in the neighbouring cell in 2006 (the first year of analysis) and the size of the cell in hundreds of hectares. Theses variables capture the expected average pressure to deforest in the cells. Details about the sources of the data can be found in Appendix **??**. This procedure allows us to build a relevant control group for each of the 9 REDD projects.

The pre-matching procedure only allows us to control for observable confounding factors. In order to control for unobservable confounding factors, we estimate the impact of the REDD projects on deforestation rates using fixed-effect estimator. The progressive involvement of the forest into the REDD projects allows us to control for all time unvarying confounding factors and to identify the impact of each project. As a matter of fact, the fixed effect estimator controls for all cell-specific effects.

We define a panel dataset with two dimensions: i corresponds to forested cells and t corresponds to the year of observation. In order to estimate the impact of REDD+ projets. First, we estimate the following model on the whole sample:

$$DefRate_{it} = \alpha + \beta REDD_{it} + \Omega Def_{it-1} + \sum_{i=1}^{1,718} \theta_i D_i + \sum_{t=1}^{7} \kappa T_t + \epsilon_{it} \tag{18}$$

Second, we estimate one model for each type of projects as displayed in Table **??**. We estimate the three following models:

$$DefRate_{it} = \alpha 1 + \beta 1 VCS_{it}^{Pri} + \sum_{i=1}^{185} \theta 1_i D_i + \sum_{t=1}^{7} \kappa 1 T_t + \epsilon_{it} \tag{19}$$

$$DefRate_{it} = \alpha 2 + \beta 2 CCB_{it}^{Pri} + \sum_{i=1}^{257} \theta 2_i D_i + \sum_{t=1}^{7} \kappa 2 T_t + \epsilon_{it} \quad (20)$$

$$DefRate_{it} = \alpha 3 + \beta 2 CCB_{it}^{Ngos} + \sum_{i=1}^{1,273} \theta 3_i D_i + \sum_{t=1}^{7} \kappa 3 T_t + \epsilon_{it} \quad (21)$$

Equations **??** to **??** are estimated on different samples. Equation **??** is estimated on the cells located in the three REDD projects that only obtained VCS certification and are managed by private-for-profit organizations (cf Table **??**), and a control group composed of all the observations obtained using pre-matching for these projects. Similarly, the samples used for equations **??** and **??** are composed of treated and control cells for the REDD projects that obtained both VCS and CCB certifications and are promoted by private-for-profit organizations (Equation **??**) and the REDD projects that obtained both VCS and CCB certifications and are promoted by NGOs (Equation **??**).

In Equations **??** to **??**, VCS_{it}^{Pri}, CCB_{it}^{Pri}, CCB_{it}^{Ngos} are respectively equals to one if cell i is located within a REDD project at time t. $DefRate_{it}$ is the deforestation rate in cell i between year t and $t-1$. We favour this measure since our cells may have slightly different sizes and propose in Section **??** a robustness test using the area deforested. D_i and T_t correspond to the individual fixed effects and yearly dummies. Introducing fixed effects allows us to control for all time unvarying confounding factors influencing both project allocation and deforestation. Yearly dummies control for all time specific effects on deforestation. Given the progressive entry into the REDD projects and our control on time-unvarying fixed effects and year-specific effects, we are confident that our approach allows us to estimate the impact of the different types of REDD projects.

In order to take into account spatial and temporal autocorrelation in the standard errors of our estimates, we rely on a correction developed by **?** and **?** using the routine proposed by **?**. This procedure allows us to estimate standard errors robust to spatial autocorrelation in a buffer of 20km (approximatively four cells) around each cells and temporal autocorrelation for three periods.

Note that in Section **??**, we analyze the validity of our matching procedure using balancing tests and placebo tests.

4.3 Results

4.3.1 Choice of a location

Table **??** presents the results of the difference-in-mean test presented in Section **??**. Given the results of the theoretical model, we expect that the projects that rely less on funding from carbon markets, here NGOs compared to private-for-profit organisations, favor more threatened forests (see Section **??**). This hypothesis is consistent with the results of the tests.

NGOs tend to enroll areas in REDD+ projects where the pressure to deforest seems higher. As can be seen in Table **??**, there were more deforestation in 2006 around the areas enrolled in a project managed by an NGO compared to the two other types of projects. However, these areas are more remote from the cities, the roads or the nearest non forested area.

Regarding certification choices, Table **??** allows us to compare the choices made by private-for-profit organisations that combine CCB and VCS certification and those that only choose VCS certification. According to the difference-in-means test, we do no find evidence of statistical difference between the two groups regarding the deforestation in neighbouring cells in 2006. However, VCS certification are located further from the roads and the urban areas that are crucial determinants of deforestation. It also confirms the theoretical predictions that proponents with a double objective favor locations with high opportunity costs since their projects are closer to the main infrastructure in order to better target the populations and achieve social objectives.

Table 3: Characteristics of location per type of projects

X	Statistic	$\bar{X}_{CCB_{it}^{Pri}}$ - $\bar{X}_{VCS_{it}^{Pri}}$	$\bar{X}_{CCB_{it}^{Ngos}}$ - $\bar{X}_{VCS_{it}^{Pri}}$	$\bar{X}_{CCB_{it}^{Ngos}}$ - $\bar{X}_{CCB_{it}^{Pri}}$
Distance to road (100km)	Mean difference	-0.2833***	0.0894**	0.3727***
	Standard-error	0.04450	0.0367	0.0319
Distance to the closest city (100km)	Mean difference	-0.1140***	0.0262	0.1402***
	Standard-error	0.0411	0.0335	0.0291
Distance to the frontier of legal Amazon (100km)	Mean difference	0.7061***	1.2782***	0.5722***
	Standard-error	0.2580	0.2105	0.1831
Distance to nearest non forested point (100km)	Mean difference	0.0010	0.0064***	0.0054***
	Standard-error	0.0019	0.0015	0.0013
Total deforestation in neighbouring cells in 2006 (100ha)	Mean difference	0.0045	4.9218***	4.9173***
	Standard-error	0.7133	0.5821	0.5063
Slope(Percent rise)	Mean difference	0.2796***	0.3201***	0.405
	Standard-error	0.0944	0.0770	0.0670

4.3.2 Additionality

The theoretical model presented above also suggests that the type of proponent and the choice of certification impacts additionality through the choice of a location. Table **??** presents the result of the estimation of equation **??** to **??**. Column (1) presents the results including the three matched samples. According to this estimation, REDD projects have negatively impacted deforestation rates. REDD projects decreased deforestation by 0.1% per year in enrolled cells. As a comparison, the yearly deforestation rate in Brazil over the period 2010-2015 is around 0.1%, according the FAO's Global Forest Resource Assessment (**?**).

Once we focus on sub-samples per type of projects, we find an additional impact of 0.16% of avoided deforestation per year for the cells included in the projects managed by NGOs (Column (3))[6]. We also find evidence of additionality for the projects that only obtained VCS certification. We find an additional impact of 0.07% of avoided deforestation per year for the cells included in the projects managed by a private-for profit organisation. Note that this impact is lower than for the projects managed by NGOs. Those results suggest that the projects managed by NGOs are more additional that the ones managed by private-for-profit organisations.

Regarding the choice of certification, we can only compare private-for-profit organisations. We have no evidence about the additionality of the projects that obtained both certifications but our results clearly suggest that the projects that only obtained VCS certification have been additional. These results confirm that the choice of a location studied in the previous Section (Table **??**) affects additionality. All these findings are consistent with our theoretical model.

4.4 Validity of the results and robustness tests

4.4.1 Placebo test

In order to test the validity of our results, we look for differences in deforestation rates before the implementation of the REDD+ projects. The two projects that started in 2002 and 2006 are not included in this these tests. The results can be found in Appendix **??**. We do not find a difference in deforestation rates in 2006 which confirms that our results can be attributed to the implementation of the REDD projects.

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[6] Remember that the size of the cells is 2,500ha

Table 4: Additionality of REDD+ projects: Deforestation rates

VARIABLES	(1) Deforestation rate	(2) Deforestation rate	(3) Deforestation rate	(4) Deforestation rate
REDD	-0.0014***			
	(0.0005)			
VCS_{it}^{Pri}		-0.0007***		
		(0.0003)		
CCB_{it}^{Pri}			0.0002	
			(0.0005)	
CCB_{it}^{Ngos}				-0.0016**
				(0.0007)
Observations	15,462	1,674	2,322	11,466
R-squared	0.0109	0.0098	0.0065	0.0146
Number of Fixed Effects	1,718	186	258	1,274
Number of yearly dummies	8	8	8	8

Standard errors in parentheses are robust to spatial autocorrelation in
a buffer of 20 km and temporal autocorrelation over three periods
*** p<0.01, ** p<0.05, * p<0.1

4.4.2 Balancing tests

In order to assess the quality of the matching procedure, we provide balancing tests for the three types of projects and their matched samples. The results of these balancing tests can be found in Appendix **??**. For each type of project, the unmatched sample includes all the cells located in the REDD projects (treated group) and the control group is composed of the cells located within a distance of 20 to 150km around each project and excluding protected areas or other REDD+ projects. The matched sample includes only the treated cells and the matched cells from the control group.

The pre-matching procedure succeeded in reducing the bias between treated and non treated observations. There are still remaining imbalances regarding some variables but we are confident that the introduction of fixed effects in the estimation allows us to control for these biases.

4.4.3 Standard-errors clustered at individual level

In our estimations, we account for spatial autocorrelation in a buffer of 20km and temporal autocorrelation over three periods in the estimation of standard errors. In the results displayed in Appendix **??**, standard errors are clustered at individual level. This procedure seems less relevant in our case given the spatial nature of our data. However, we provide the results as a robustness tests. The results confirm our previous findings.

4.4.4 Area deforested

Given that our observations have heterogeneous sizes, we choose to use the yearly deforestation rates as our endogenous variable. However, we propose to test the robustness of our results using the number of hectares deforested as endogeneous variable. As a matter of fact, using deforestation rates, our results could be driven by deforestation in small cells that would result in very high deforestation rates.

The result of the estimation can be found in the Appendix **??**. The results confirm our finding regarding the additionality of the projects managed by NGOs and private-for-profit organisations that only obtained VCS certification. We find an average impact of 1.97 hectares of yearly avoided deforestation for the whole sample, 0.68 for the the projects that only obtained VCS certification and 2.21 for the projects managed by a private-for profit organisation. Moreover, the magnitude of the coefficient is in line with our previous findings. If we multiply the average size of a forested cell (1,900 hectares) by the decrease in deforestation rates estimated in Table **??**, the magnitude is similar to the coefficient estimated[7]. As in Table **??**, we do not find evidence of a significant impact for the projects that obtained both certifications.

5 Conclusion

In this article, we study the interactions between the type of project proponent, the choice of a location and the choice of a certification scheme in the context of REDD+ projects. To study this issue, we develop a theoretical model and test the results on an original database of REDD+ projects in Brazil. According to our results, location and additionality from the projects are closely related to the project proponent preferences. Projects are likely to have stronger additionality when the project proponents have larger preferences for environmental quality, and smaller preferences

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[7] For the whole sample:0.0014x1900=2.66; For the VCS projects: 0.0007x1900=1.33; For the NGOs projects: 0.0016*1900=3.04

for funding from voluntary markets. Moreover, the trade off between project opportunity cost and the efficiency of the environmental effort is crucial. Because higher opportunity costs decreases environmental efficiency, it might be optimal in order to maximise funding from carbon markets to implement the project in non additional area.

Our empirical analysis supports these predictions. As a matter of fact, according to our estimations, the projects that only obtained VCS certification had an additional impact on the deforestation We can not reject that the private projects that combined both CCB and VCS certification were not additional even though they are located in areas with higher opportunity costs. Moreover, NGOS tend to rely less on the carbon market for funding and the project supported by these actors were located in more threatened areas and were more additional.

Given the conclusions of our theoretical model, we acknowledge that our approach suffers from our lack of data regarding the social impact of REDD+ projects. As a matter of fact, the theoretical model considers both social and environmental benefits. The empirical analysis confirms the results regarding deforestation but, unfortunately, we are unable to confirm the results of the model regarding social benefits. Moreover, we were only able to georeference 9 REDD projects so our results rely on very small sample of projects. In order to increase external validity of our results, it would be interesting to expand it to other projects.

Our analysis provides innovative theoretical and empirical evidence regarding the mechanisms that leads to additionality. We show how the incentives behind REDD+ can lead to lower environmental effort. Following recent calls by **?**, among others, we do not wonder if REDD+ projects are effective instruments for forest conservation but how and under which conditions they deliver the expected results. We believe that this focus on the mechanisms is a crucial issue that needs to be tackled by academics in order to improve our understanding of conservation policies.

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Appendices

A Value of the parameters for the simulations

Table 5: default

Variable	Value
b_i	$\in [1; 5]$
v	5
δ_i	$\frac{1}{b_i^a}$
a	1.8
p_c	1, 0.8
p_u	0.1, 0.3, 1.5, 2
γ_c	1
γ_u	1

B Data sources

Table 6: Data sources

Variable	Source
Distance to waters (100km)	Digital Chart of the World
Distance to road (100km)	Digital Chart of the World
Distance to the closest urban area (100km)	IBGE
Distance to the frontier of legal Amazon (100km)	IBGE
Distance to first non-forest point (100km)	PRODES
Elevation (Meters)	SRTM
Slope (Percentage rise)	SRTM
Total deforestation in neighbouring cells in 2006 (100ha)	PRODES
REDD+ projects	ID-RECCO

C Placebo test

Table 7: Parallel trend: Difference in deforestation in 2006 between treated and matched controls

Type	Statistics	Observations	Treated	Untreated	Difference
VCS_{it}^{Pri}	Mean difference	41	0,0004	0,0002	0,0002
	Standard-error	41	0,0002	0,0002	0,0003
CCB_{it}^{Pri}	Mean difference	129	0,002	0,0003	0,0018
	Standard-error	129	0,0014	0,0001	0,0014
CCB_{it}^{Ngos}	Mean difference	435	0,0098	0,0076	0,0022
	Standard-error	435	0,0015	0,0009	0,0018

D Balancing tests

Table 8: Balancing tests VCS^{Pri}

Variable	Matched	Treated	Control	% Bias	% Reduction bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.2639	0.3784	-38.3		-3.33	0.001***
	Matched	0.2639	0.2770	-4.4	88.6	-0.28	0.780
Distance to road	Unmatched	0.8972	0.6202	61.3		4.43	0.000***
	Matched	0.8972	0.9358	-8.5	86.1	-0.76	0.447
Distance to the closest urban area (100km)	Unmatched	0.5460	0.4047	39.1		4.25	0.000***
	Matched	0.5460	0.5023	12.1	69.1	0.70	0.487
Distance to the frontier of legal Amazon (100km)	Unmatched	8.4404	7.9369	27.6		2.10	0.036**
	Matched	8.4404	8.3560	4.6	83.2	0.45	0.653
Distance to nearest non forested area (100km)	Unmatched	0.0004	0.0041	-29.2		-2.01	0.045**
	Matched	0.0004	0.0012	-5.9	79.8	-1.52	0.129
Total deforestation in neighbouring cells in 2006 (100ha)	Unmatched	0.0571	0.6834	-60.6		-4.14	0.000***
	Matched	0.0571	0.0690	-1.1	98.1	-0.45	0.656
Slope (Percent Rise)	Unmatched	0.5708	0.9400	-51.6		-4.55	0.000***
	Matched	0.5708	0.5569	1.9	96.2	0.15	0.878
Elevation (Meters)	Unmatched	71.4630	116.3200	-60.0		-4.96	0.000***
	Matched	71.4630	76.2970	-6.5	89.2	-0.51	0.610
Area	Unmatched	14.6540	15.7890	-18.7		-1.70	0.089*
	Matched	14.6540	19.4690	-79.2	-324.2	-5.14	0.000***

Table 9: Balancing tests CCB^{Pri}

Variable	Matched	Treated	Control	% Bias	% Reduction bias	t-stat	p-value
Distance to waters (100km)	Unmatched	.1080	.2692	-89.0		-4.66	0.000***
	Matched	.1080	.1178	-5.4	93.9	-0.47	0.638
Distance to road	Unmatched	.2279	.3603	-52.2		-3.35	0.001***
	Matched	.2279	.2261	0.7	98.6	0.04	0.971
Distance to the closest urban area (100km)	Unmatched	.2528	.3841	-60.9		-3.30	0.001***
	Matched	.2528	.2321	9.6	84.2	0.61	0.541
Distance to the frontier of legal Amazon (100km)	Unmatched	9.5974	8.8882	31.4		2.09	0.037**
	Matched	9.5974	9.7279	-5.8	81.6	-0.31	0.756
Distance to nearest non forested area (100km)	Unmatched	.0030	.0005	35.7		4.02	0.000***
	Matched	.0030	.0011	27.1	24.2	1.19	0.235
Total deforestation in neighbouring cells in 2006 (100ha)	Unmatched	.1298	.5519	-46.2		-2.32	0.020**
	Matched	.1298	.1047	2.7	94.1	0.81	0.422
Slope (Percent Rise)	Unmatched	1.6546	1.0501	58.8		4.26	0.000***
	Matched	1.6546	1.3838	26.3	55.2	0.97	0.336
Elevation (Meters)	Unmatched	121.1400	95.2510	39.0		2.35	0.019**
	Matched	121.1400	106.8400	21.5	44.8	0.94	0.350
Area	Unmatched	15.8600	16.0000	-2.2		-0.17	0.866
	Matched	15.8600	14.9390	14.7	-558.8	0.75	0.454

Table 10: Balancing tests CCB^{Ngos}

Variable	Matched	Treated	Control	% Bias	% Reduction bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.3817	0.4633	-18.0		-4.49	0.000***
	Matched	0.3817	0.3626	4.2	76.6	0.73	0.466
Distance to road	Unmatched	0.9866	0.8991	17.5		3.51	0.000***
	Matched	0.9866	0.9507	7.2	59.0	1.49	0.137
Distance to the closest urban area (100km)	Unmatched	0.5721	0.6720	-28.9		-6.46	0.000***
	Matched	0.5721	0.6771	-30.4	-5.1	-5.66	0.000***
Distance to the frontier of legal Amazon (100km)	Unmatched	9.7186	10.0940	-16.0		-3.58	0.000***
	Matched	9.7186	9.8283	-4.7	70.8	-0.96	0.340
Distance to nearest non forested area (100km)	Unmatched	0.0069	0.0160	-31.6		-6.09	0.000***
	Matched	0.0069	0.0156	-30.1	4.8	-5.76	0.000***
Total deforestation in neighbouring cells in 2006 (100ha)	Unmatched	4.9789	.3644	105.8		62.14	0.000***
	Matched	4.9789	.9855	91.6	13.5	15.65	0.000***
Slope (Percent Rise)	Unmatched	0.8909	1.0626	-22.1		-4.77	0.000***
	Matched	0.8909	0.9220	-4.0	81.9	-0.90	0.369
Elevation (Meters)	Unmatched	174.9700	173.5900	1.4		0.30	0.763
	Matched	174.9700	164.6500	10.3	-648.7	2.09	0.037**
Area	Unmatched	19.9400	20.6870	-12.5		-3.07	0.002***
	Matched	19.9400	21.5290	-26.6	-112.8	-5.11	0.000***

Figure 6: Balancing tests VCS^{Pri}

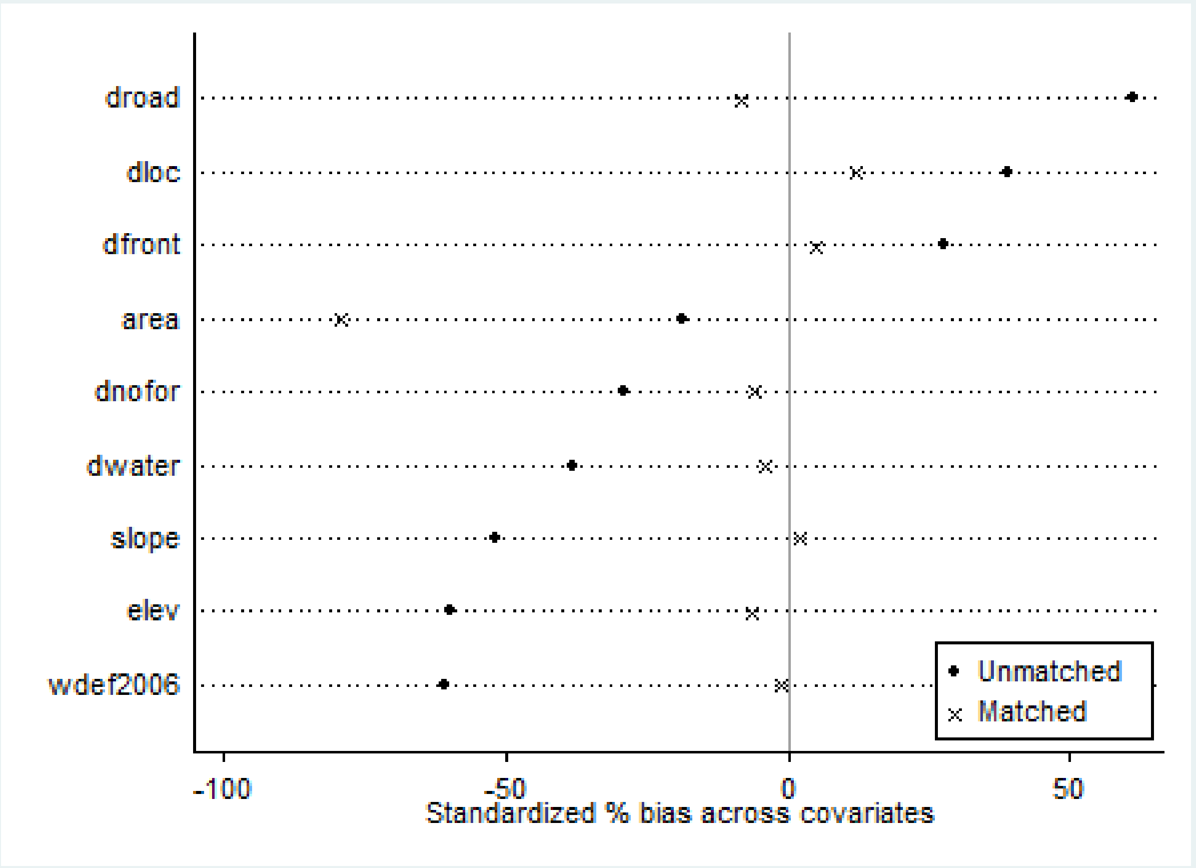


Figure 7: Balancing tests CCB^{Pri}

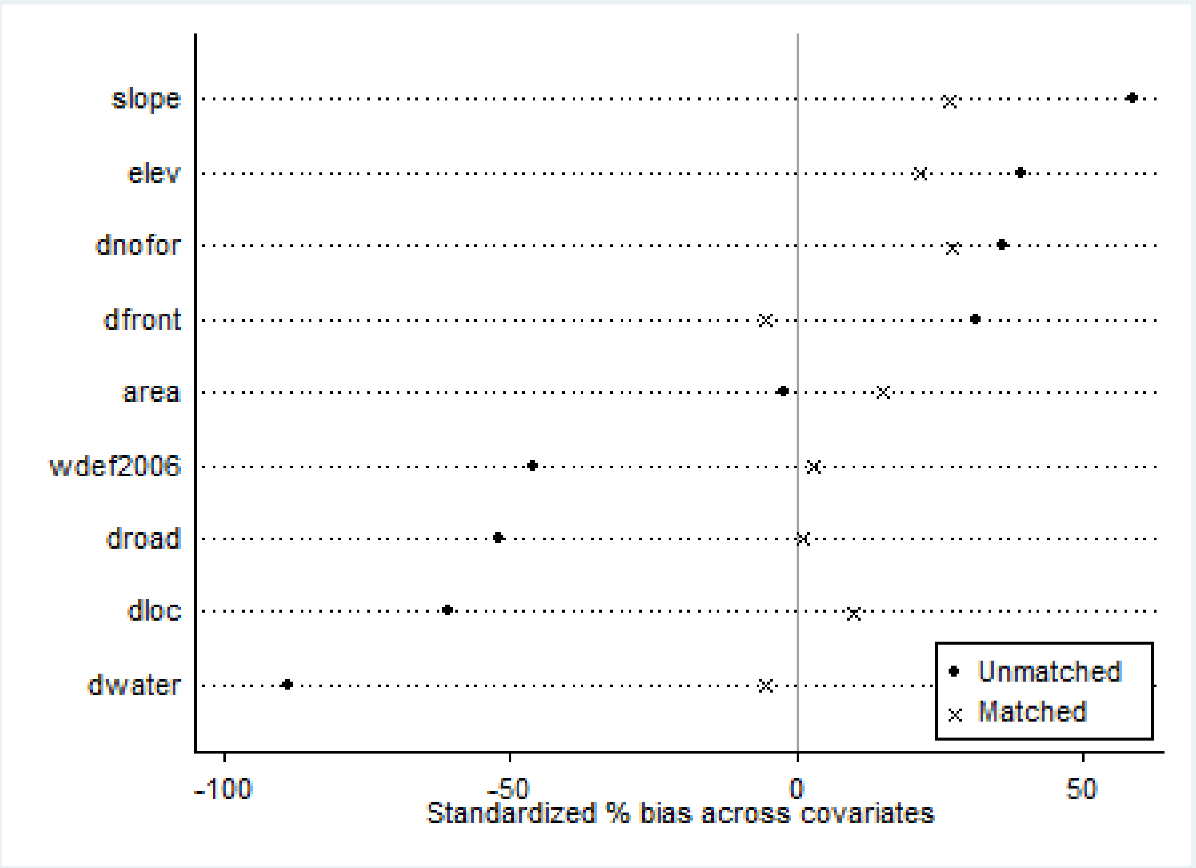
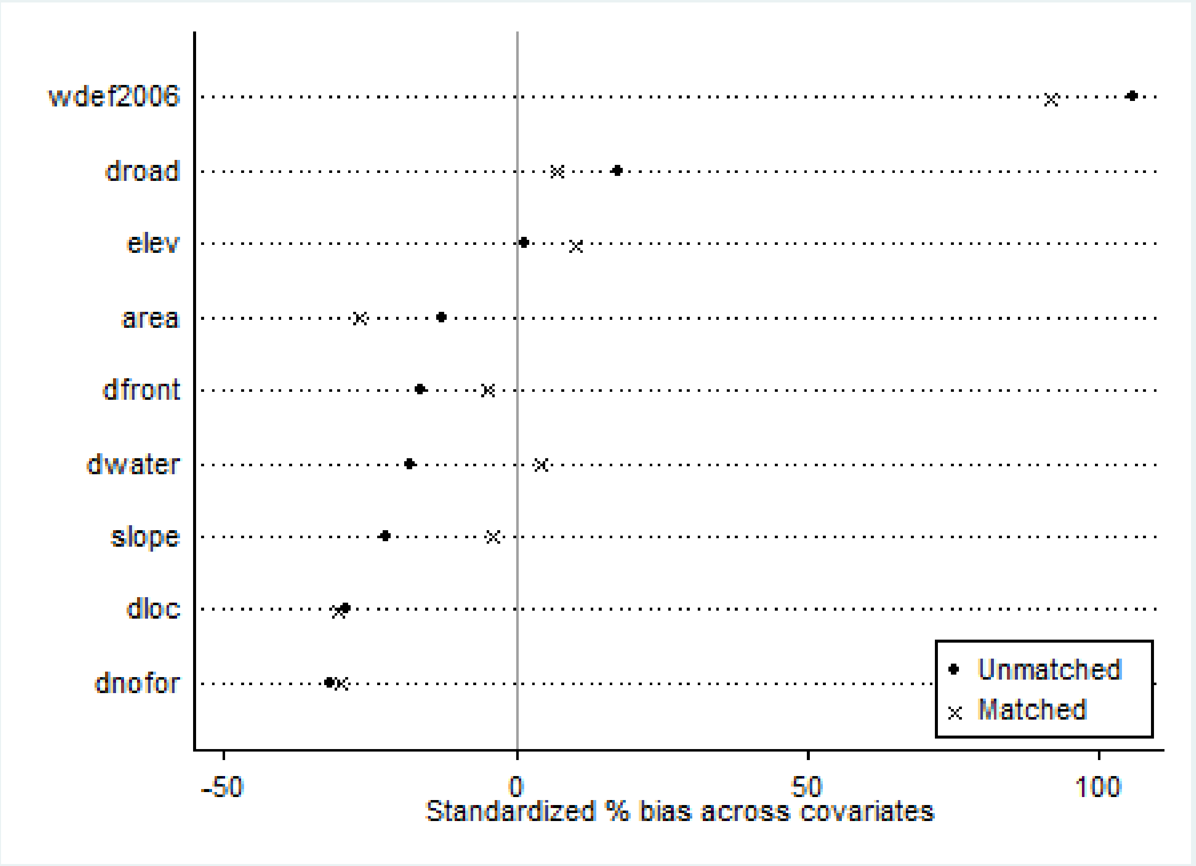


Figure 8: Balancing tests CCB^{Ngos}



E Standard errors clustered at individual level

Table 11: Robustness test: Standard errors clustered at individual level

	(1)	(2)	(3)	(4)
VARIABLES	Deforestation rate	Deforestation rate	Deforestation rate	Deforestation rate
REDD	-0.0014**			
	(0.0006)			
VCS_{it}^{Pri}		-0.0007**		
		(0.0003)		
CCB_{it}^{Pri}			0.0007	
			(0.0006)	
CCB_{it}^{Ngos}				-0.0016*
				(0.0009)
Constant	0.0048***	0.0003**	0.0010*	0.0062***
	(0.0004)	(0.0001)	(0.0005)	(0.0005)
Observations	15,462	1,674	2,322	11,466
R-squared	0.0109	0.0098	0.0065	0.0146
Number of Fixed Effects	1,718	186	258	1,274
Number of yearly dummies	8	8	8	8

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6 Area deforested

Table 12: Additionality of REDD+ projects: Area deforested

	(1)	(2)	(3)	(4)
VARIABLES	Area deforested	Area deforested	Area deforested	Area deforested
REDD	-1.9687***			
	(0.7803)			
VCS_{it}^{Pri}		-0.6776***		
		(0.2442)		
CCB_{it}^{Pri}			0.5356	
			(0.4649)	
CCB_{it}^{Ngos}				-2.2056**
				(1.0760)
Observations	15,462	1,674	2,322	11,466
R-squared	0.0142	0.0074	0.0116	0.0193
Number of Fixed Effects	1,718	186	258	1,274
Number of yearly dummies	8	8	8	8

Standard errors in parentheses are robust to spatial autocorrelation in a buffer of 20 km and temporal autocorrelation over three periods

*** p<0.01, ** p<0.05, * p<0.1