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

Philippe Delacote ^{*†‡}; Gwenole Le Velly ^{§¶}; Gabriela Simonet ^{||**}

September 4, 2017

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.

JEL codes: Q23; Q28; Q56

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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

33 additionality of projects. In the fourth section, our theoretical insights are tested, using an original
34 database obtained through georeferencing of 9 REDD+ projects in Brazil. We empirically study
35 both the determinants of the location choice according to the type of project proponents and the
36 certification scheme, and the additionality of each type of projects. To estimate additionality,
37 we rely on impact evaluation methodologies as recommended in the recent literature about forest
38 conservation policy instruments (??). Section five concludes and makes recommendations for the
39 implementation of REDD+ projects.

40 2 Context

41 2.1 The REDD+ mechanism

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

60 Although REDD+ was initially proposed as a national mechanism, pilot activities were en-
61 couraged during COP 13 in Bali (?). As of September 2016, over 300 REDD+ projects are being
62 implemented across the tropics (?). Among the various sources of funding used by REDD+ projects
63 proponents, 69 percent of the projects plan to sell carbon credits (?). The forest carbon credits

64 generated by REDD+ projects are well represented in the voluntary carbon markets. Indeed, in
65 2015, REDD+ projects (including tree-planting and improved forest management) generated 18
66 percent (or 15 megatons of CO₂ equivalent) of the total volume of offsets transacted in this market
67 (?).

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

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

96 2.2 Certification standards

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

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

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

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

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

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

142 3 Modelling additionality and location selection

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

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

151 3.1 Business-as-usual cases

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

$$\max_{d_i} u_i = b_i d_i - \frac{v}{2} d_i^2 \quad (1)$$

156 Under no intervention, the optimal level of deforestation is thus: $\bar{d}_i = \frac{b_i}{v}$. The level of livelihoods
157 is: $\bar{u}_i = \frac{b_i^2}{2v}$. Those levels are considered as the business-as-usual scenarios.

158 3.2 REDD+ project

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

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

168 3.3 Community's reaction to the REDD+ project

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

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

181 The representative agent's utility thus becomes:

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

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

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

$$d_i^*(e) = \frac{b_i}{v} \frac{1}{(1 + \delta_i e)^2} \quad (3)$$

$$u_i^*(e) = \frac{b_i^2}{2v} \frac{(2 - \delta_i e)}{(1 + \delta_i e)^2} \quad (4)$$

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

$$d'_{ie} = \frac{\partial d_i^*(e)}{\partial e} = \frac{b_i}{v} \frac{-2\delta_i}{(1 + \delta_i e)^3} < 0 \quad (5)$$

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

184 Avoided deforestation from the project is:

$$AD_i(e) = \bar{d}_i - d_i^*(e) = \frac{b_i}{v} \frac{\delta_i e(2 + \delta_i e)}{(1 + \delta_i e)^2} \quad (7)$$

185 Avoided deforestation is increasing in e :

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

186 Livelihoods improvement from the project is:

$$\Delta_i(e) = u_i^*(e) - \bar{u}_i = \frac{b_i^2}{2v} \frac{(1 - \delta_i^2 e^2 - 3\delta_i e)}{(1 + \delta_i e)^2} \quad (9)$$

$$\Delta'_{ie} = \frac{b_i^2}{2v} \frac{\delta_i(\delta_i e - 5)}{(1 + \delta_i e)^3} < 0 \iff \delta_i < 5/e \quad (10)$$

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

189 3.4 A simple model of effort allocation in a REDD+ project

190 3.4.1 Optimal effort allocation

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

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

195 We consider that utility from environmental improvement (U_E), utility from livelihood improve-
 196 ment (U_L) and utility from project funding (U_F) are all increasing and concave.²

197 $AD_i(e)$ is the actual level of avoided deforestation (supposedly known by the Pp). $\Delta_i(e)$ is the
 198 project impacts in terms of livelihood improvement. $p_{cm}(\gamma_{cm}\bar{d}_i - d_i^*(e))$ is the amount of money
 199 received from selling REDD+ credits on voluntary markets under certification m . p_{cm} is the price
 200 of carbon credits, while γ_{cm} is the level of stringency relating avoided deforestation to credits.
 201 A low (< 1) γ_{cm} represents strong requirements and/or low uncertainty in baseline estimation,
 202 while a large (> 1) γ_{cm} represents low levels of stringency and/or high uncertainty regarding the
 203 baseline. $p_{um}(u_i^*(e) - \gamma_{um}\bar{u}_i)$ represents the payment related to livelihoods improvement under
 204 certification m . p_{um} is the price premium that may be paid to the project proponent if such co-
 205 benefit is taken into account by the certification scheme³. γ_{um} is the stringency level of livelihood
 206 improvement measurements. If $\gamma_{um} < 1$, the initial level of livelihoods is underestimated, which
 207 tends to overestimate livelihoods improvements. Thus the label is considered loose in terms of
 208 livelihoods measurements. In contrast, it is considered stringent if $\gamma_{um} > 1$.

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

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

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

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

216 3.4.2 What drives effort allocation?

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

²Log functions will be used for the simulations.

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

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

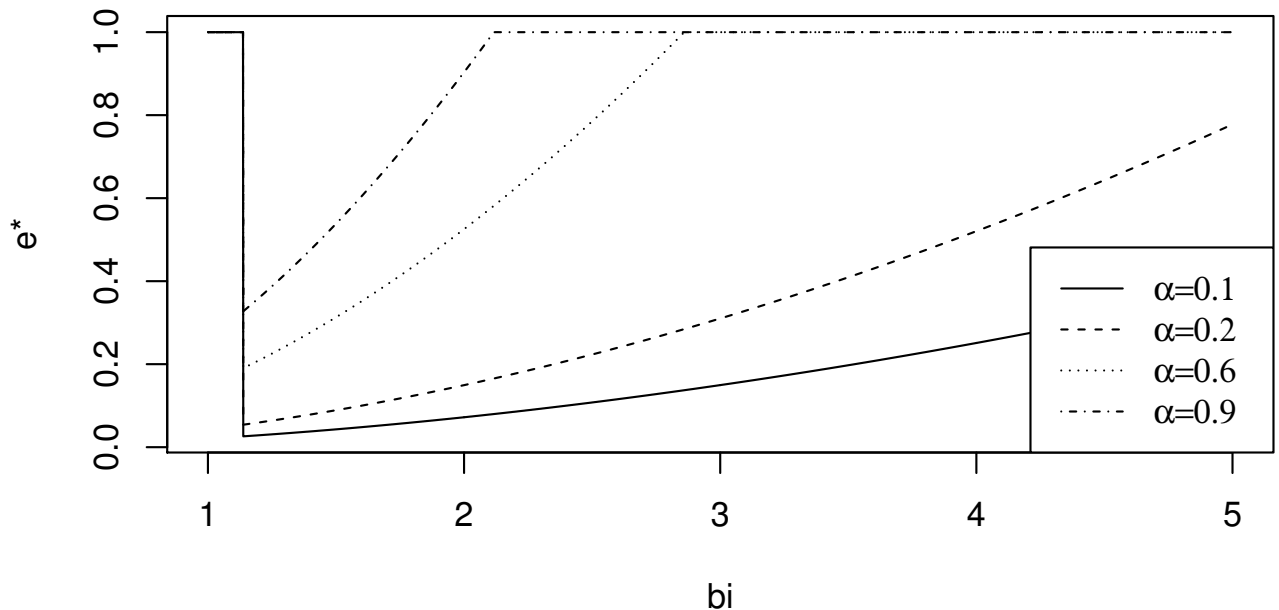
224 **NoMo Case:** ($\alpha + \beta = 1$) .

225 When the project proponent does not consider external funding in its objective function, the
 226 effort allocation e^* is increasing in α and decreasing in β . Moreover, the optimal effort allocation
 227 is increasing in b_i : the marginal effort efficiency is increasing in b_i for both environmental and
 228 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
 229 $\frac{\partial AD'_{ie}}{\partial \delta_i} < 0$ and $\frac{\partial \Delta'_{ie}}{\partial \delta_i} > 0$).

230

231 **Result 1 :** *When the project proponent does not focus on external funding from carbon markets,*
 232 *his environmental effort allocation e^* increases in environmental preferences α , decreases in liveli-*
 233 *hood preferences β , increases in the community marginal benefit b_i and increases in environmental*
 234 *effort efficiency δ_i . If the environmental effort efficiency is decreasing in the marginal benefit from*
 235 *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



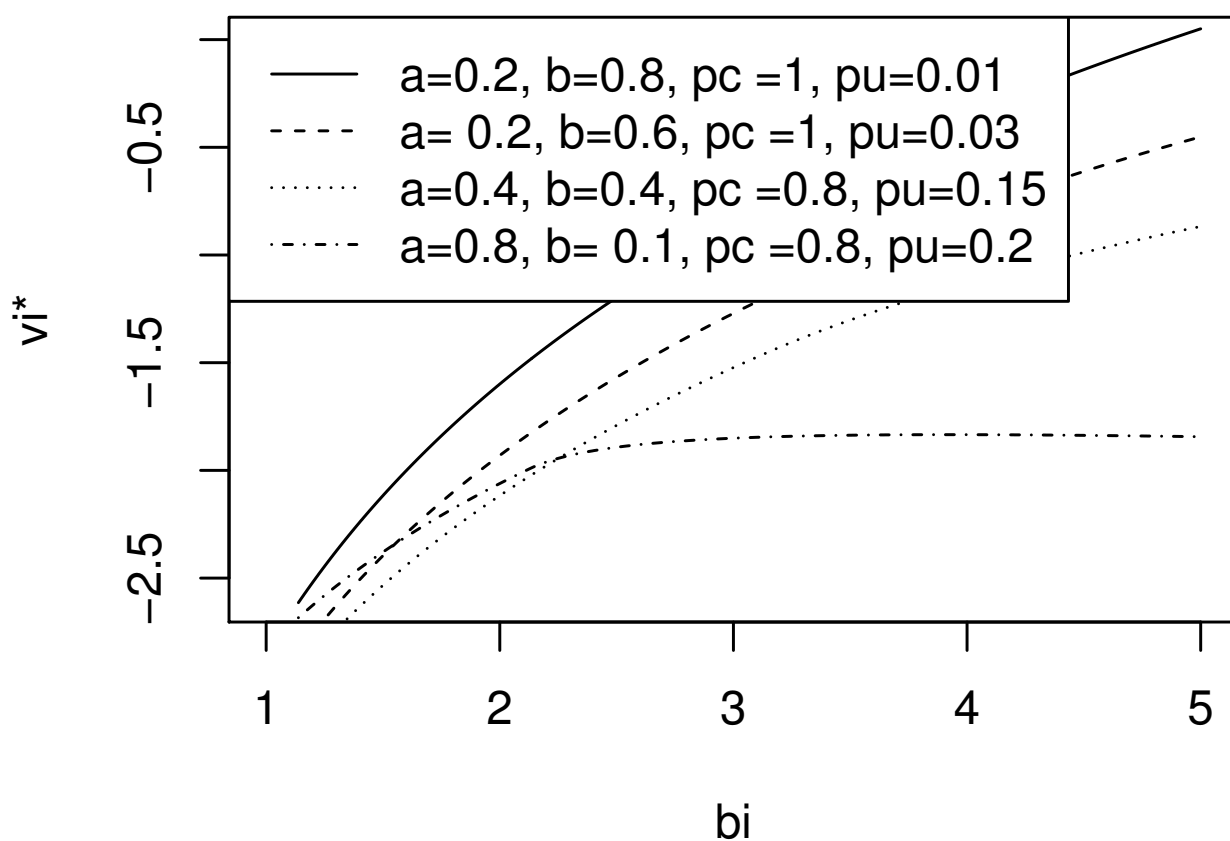
236 **OnMo Case:** $(\alpha + \beta = 0)$.

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

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

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

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

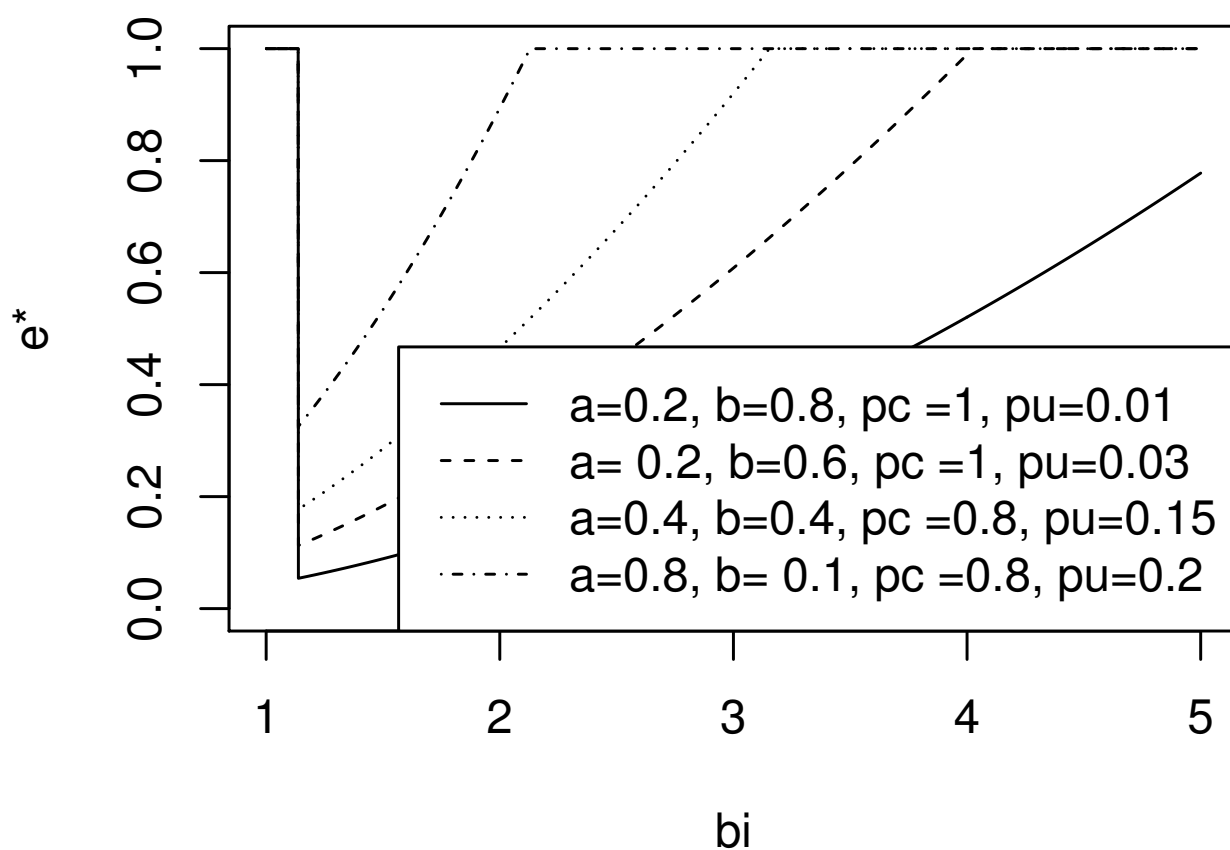


244 **BoMo Case:** ($0 < \alpha + \beta < 1$) .

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

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

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

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

254 3.5 Choosing project location

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

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

263 The project location is chosen so that:

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

264 Location i is chosen if the following condition is satisfied:

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

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

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

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

279

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

282 *efit whatever his preferences in terms of avoided deforestation, livelihoods, or certification funding.*
 283 *If the marginal benefit has a large effect on the environmental effort efficiency ($\frac{\partial \delta_i}{\partial b_i} < 0$ and large*
 284 *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

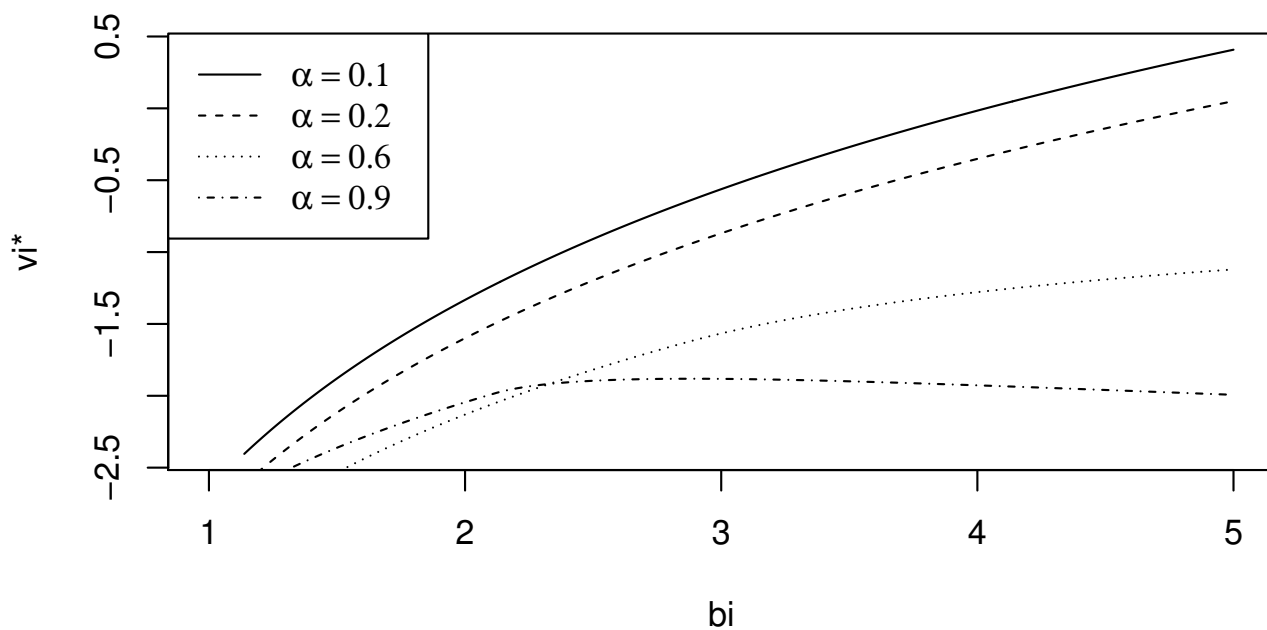
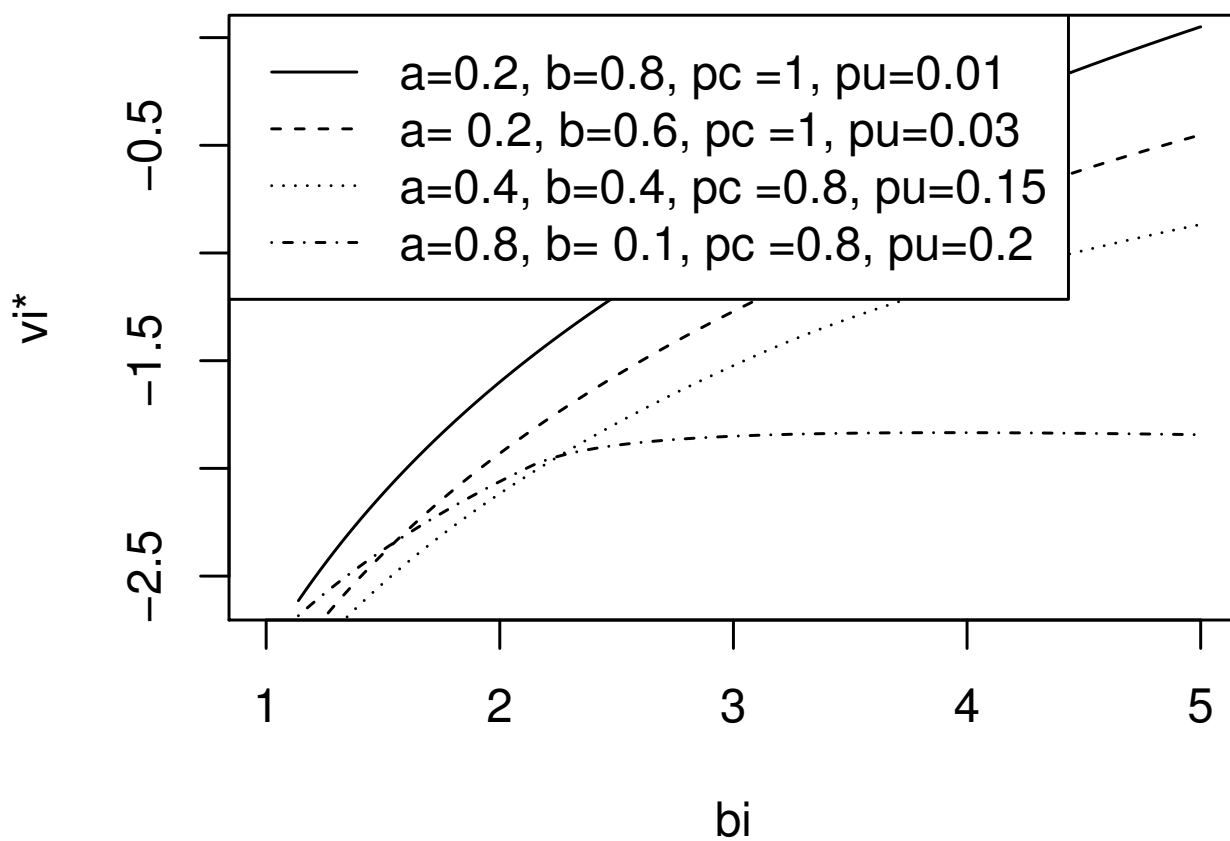


Figure 5: Project value for diverse values of b_i , α , β , p_c , p_u , *BoMo case*



285 3.6 Choosing the certification scheme

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

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

290 Location i is chosen if the following condition is satisfied:

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

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

293 3.7 Testable Hypotheses

294 According to the results of our theoretical model, the objectives of the project proponents influ-
295 ence his choice of a location, defined by a marginal benefit b_i and an environmental effort efficiency
296 $\delta_i(b_i)$, his environmental effort e and the certification scheme. We also show that interactions
297 between b_i and $\delta_i(b_i)$ influence the environmental effort.

298 We can hypothesize that b_i strongly and negatively influences the environmental effort efficiency
299 $\delta_i(b_i)$. In this case, we can show that the Pp will provide lower environmental effort (Result 1 and
300 2). This is especially the case when the Pp is only motivated by funding from carbon markets
301 ($\alpha = 0$ and $\beta = 0$): this case converges towards a corner solution where his environmental effort e_i
302 is null. Note that, if the level of environmental stringency of the carbon standard is low ($\gamma_{cm} > 1$) i.e.
303 if the baseline of deforestation is overestimated, the Pp can still get funding from carbon markets
304 even if his environmental effort is null.

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

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

- 312 • A Pp only motivated by funding from carbon markets favors areas with lower (or null) op-
313 portunity costs and generates less additionality.
- 314 • A Pp that chooses a double certification favor areas with high opportunity costs but generates
315 less additionality.

316 4 Empirical analysis

317 4.1 Data

318 ? built an international database of REDD+ projects around the world. This database is
319 available online⁴ and contains 454 projects located in 56 countries. As of May 2017, the database
320 included information about 57 projects in Brazil, of which 31 are ongoing projects of avoided defor-
321 estation (REDD). However, a vast majority of these projects were not certified. Given the scope of
322 this article, we focus on projects that relied, or will soon rely, on funds coming from the voluntary
323 carbon markets. Therefore, we choose to focus on projects that already obtained the VCS and/or
324 the CCB certifications. Moreover, we choose to focus on conservation projects (REDD) instead of
325 reforestation ones for two reasons. First, it is easier to monitor deforestation than reforestation us-
326 ing satellite images. Second, reforestation projects are smaller, making georeferencing complicated
327 if not impossible.

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

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

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

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

354 In order to estimate the impact of the project on deforestation, we use deforestation data
 355 provided by PRODES⁵. PRODES is a national program that provides geographic data about de-
 356 forestation and forest cover in the Legal Amazon between 2006 and 2014, based on Landsat images
 357 of 20 to 30 meter resolution. Except for one project, the georeferenced projects all started dur-
 358 ing this period of analysis. As we will explain in the next section, this progressive entry into the
 359 REDD+ mechanism allows us to estimate the impact of the program using panel estimations. The
 360 starting dates of the REDD+ projects are detailed in Table ??.

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

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

364 analysis using PRODES data and create a new shape file of forested cells. All non forested areas in
 365 2005 are excluded from our sample. Eventually, we intersect this shape file with the REDD projects
 366 and protected areas boundaries. Therefore, each forested cell is either entirely within or outside
 367 protected areas and/or REDD projects. This procedure allows us to compute yearly deforestation
 368 between 2006 and 2014 within each cell. We drop cells of less than 1000 hectares as they mainly
 369 result from mis-overlap and may bias our results.

370 4.2 Methods

371 4.2.1 Choice of a location

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

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

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

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

$$H0 : \bar{X}_i - \bar{X}_j = 0$$

$$H1 : \bar{X}_i - \bar{X}_j \neq 0$$

392 4.2.2 Additionality

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

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

407 In order to obtain a valid estimation of the impact, the Stable Unit of Treatment Value As-
408 sumption (SUTVA) must hold. This hypothesis requires that the outcome of an observation, here
409 deforestation, is only influenced by its own status regarding the treatment. In our case, it means
410 that the project does not impact deforestation in the control group. For this reason, we consider
411 that the direct buffer of 20km around the projects (approx. the four closest cells from the project)
412 is likely to be influenced by the project through leakage for instance (?). If we do not exclude
413 the neighboring cells, the SUTVA hypothesis would not hold and the estimation might be biased.
414 However, in order to identify the impact of the projects, the choice of the control and treated
415 groups must take into account unobservable confounding factors that affect both deforestation and
416 the location of the REDD projects. By restricting our control group to the cells that are located

417 no further than 150km from the REDD project, we hope to balance unobservable covariates such
 418 as agro-ecological conditions. We also exclude protected areas and/or other REDD+ projects from
 419 the control group since they also are under conservation policies.

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

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

423 X_{li} is a vector of L variables including geographic characteristics that are structural deter-
 424 minants of deforestation (???) such as distances to the closest waters, roads and localities, the
 425 distance to the Amazon frontier that we approximate by the distance to the border of the Eastern
 426 States of Mato Grosso and Para, distance to the first non-forest point, slope in percent rise, ele-
 427 vation in meters and the number of hectares of deforestation in the neighbouring cell in 2006 (the
 428 first year of analysis) and the size of the cell in hundreds of hectares. Theses variables capture the
 429 expected average pressure to deforest in the cells. Details about the sources of the data can be
 430 found in Appendix ???. This procedure allows us to build a relevant control group for each of the
 431 9 REDD projects.

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

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

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

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

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

$$DefRate_{it} = \alpha_2 + \beta_2 CCB_{it}^{Pri} + \sum_{i=1}^{257} \theta_2 D_i + \sum_{t=1}^7 \kappa_2 T_t + \epsilon_{it} \quad (20)$$

$$DefRate_{it} = \alpha_3 + \beta_3 CCB_{it}^{Ngos} + \sum_{i=1}^{1,273} \theta_3 D_i + \sum_{t=1}^7 \kappa_3 T_t + \epsilon_{it} \quad (21)$$

443 Equations ?? to ?? are estimated on different samples. Equation ?? is estimated on the cells
 444 located in the three REDD projects that only obtained VCS certification and are managed by
 445 private-for-profit organizations (cf Table ??), and a control group composed of all the observations
 446 obtained using pre-matching for these projects. Similarly, the samples used for equations ?? and ??
 447 are composed of treated and control cells for the REDD projects that obtained both VCS and CCB
 448 certifications and are promoted by private-for-profit organizations (Equation ??) and the REDD
 449 projects that obtained both VCS and CCB certifications and are promoted by NGOs (Equation
 450 ??).

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

460 In order to take into account spatial and temporal autocorrelation in the standard errors of
 461 our estimates, we rely on a correction developed by ? and ? using the routine proposed by ?.
 462 This procedure allows us to estimate standard errors robust to spatial autocorrelation in a buffer of
 463 20km (approximately four cells) around each cells and temporal autocorrelation for three periods.

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

466 4.3 Results

467 4.3.1 Choice of a location

468 Table ?? presents the results of the difference-in-mean test presented in Section ??. Given the
 469 results of the theoretical model, we expect that the projects that rely less on funding from carbon

470 markets, here NGOs compared to private-for-profit organisations, favor more threatened forests
471 (see Section ??). This hypothesis is consistent with the results of the tests.

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

476 Regarding certification choices, Table ?? allows us to compare the choices made by private-
477 for-profit organisations that combine CCB and VCS certification and those that only choose VCS
478 certification. According to the difference-in-means test, we do not find evidence of statistical differ-
479 ence between the two groups regarding the deforestation in neighbouring cells in 2006. However,
480 VCS certification are located further from the roads and the urban areas that are crucial determi-
481 nants of deforestation. It also confirms the theoretical predictions that proponents with a double
482 objective favor locations with high opportunity costs since their projects are closer to the main
483 infrastructure in order to better target the populations and achieve social objectives.

Table 3: Characteristics of location per type of projects

\bar{X}	Statistic	$\bar{X}_{CCB}^{Pri} - \bar{X}_{VCS}^{Pri}$	$\bar{X}_{CCB}^{Ngos} - \bar{X}_{VCS}^{Pri}$	$\bar{X}_{CCB}^{Ngos} - \bar{X}_{CCB}^{Pri}$
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

484 4.3.2 Additionality

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

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

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

504 4.4 Validity of the results and robustness tests

505 4.4.1 Placebo test

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

⁶Remember 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

511 4.4.2 Balancing tests

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

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

522 4.4.3 Standard-errors clustered at individual level

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

528 4.4.4 Area deforested

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

534 The result of the estimation can be found in the Appendix ??. The results confirm our finding
535 regarding the additionality of the projects managed by NGOs and private-for-profit organisations
536 that only obtained VCS certification. We find an average impact of 1.97 hectares of yearly avoided
537 deforestation for the whole sample, 0.68 for the the projects that only obtained VCS certification
538 and 2.21 for the projects managed by a private-for profit organisation. Moreover, the magnitude
539 of the coefficient is in line with our previous findings. If we multiply the average size of a forested
540 cell (1,900 hectares) by the decrease in deforestation rates estimated in Table ??, the magnitude
541 is similar to the coefficient estimated⁷. As in Table ??, we do not find evidence of a significant
542 impact for the projects that obtained both certifications.

543 5 Conclusion

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

⁷For the whole sample: $0.0014 \times 1900 = 2.66$; For the VCS projects: $0.0007 \times 1900 = 1.33$; For the NGOs projects: $0.0016 \times 1900 = 3.04$

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

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

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

567 Our analysis provides innovative theoretical and empirical evidence regarding the mechanisms
568 that leads to additionality. We show how the incentives behind REDD+ can lead to lower environ-
569 mental effort. Following recent calls by ?, among others, we do not wonder if REDD+ projects are
570 effective instruments for forest conservation but how and under which conditions they deliver the
571 expected results. We believe that this focus on the mechanisms is a crucial issue that needs to be
572 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	$\frac{1}{b_i^2}$
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 $VCSP_{ri}$

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 $CCB^{N_{gos}}$

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}

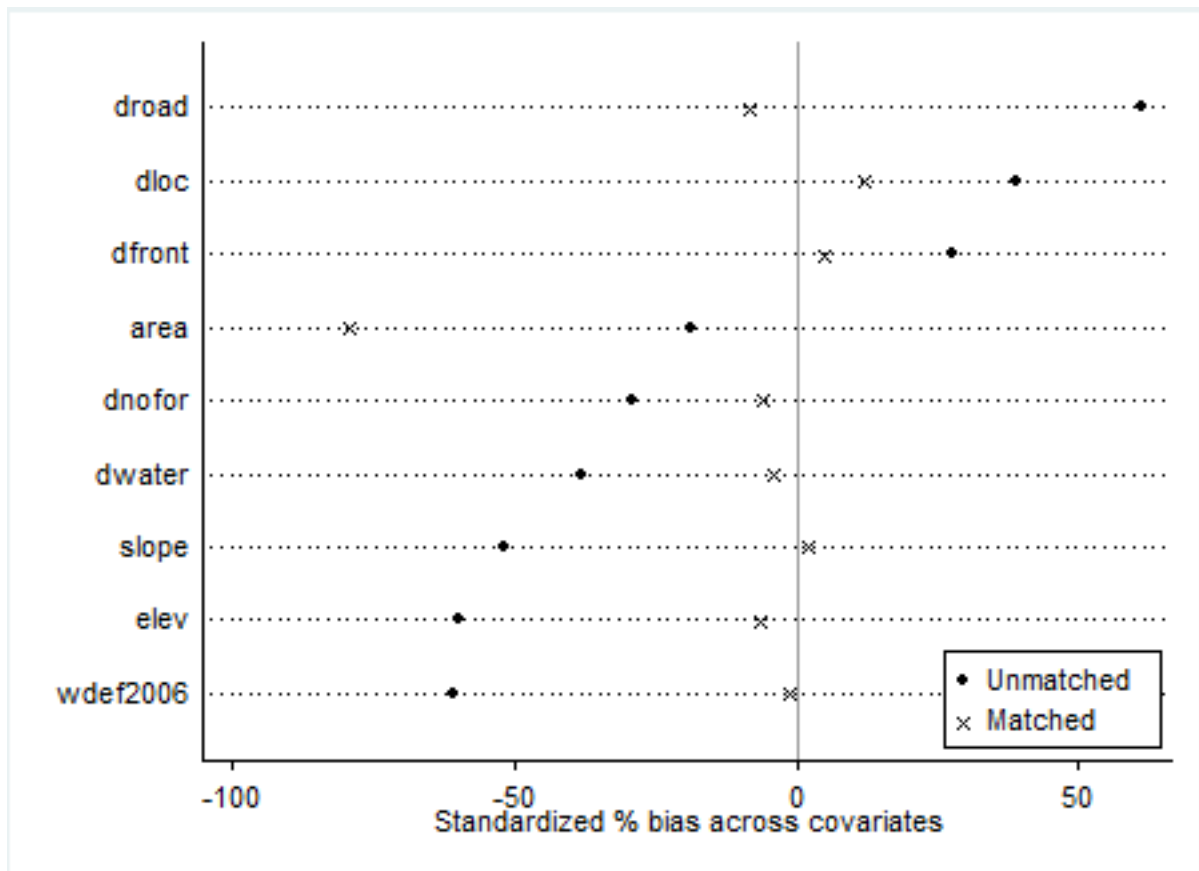


Figure 7: Balancing tests CCB^{Pri}

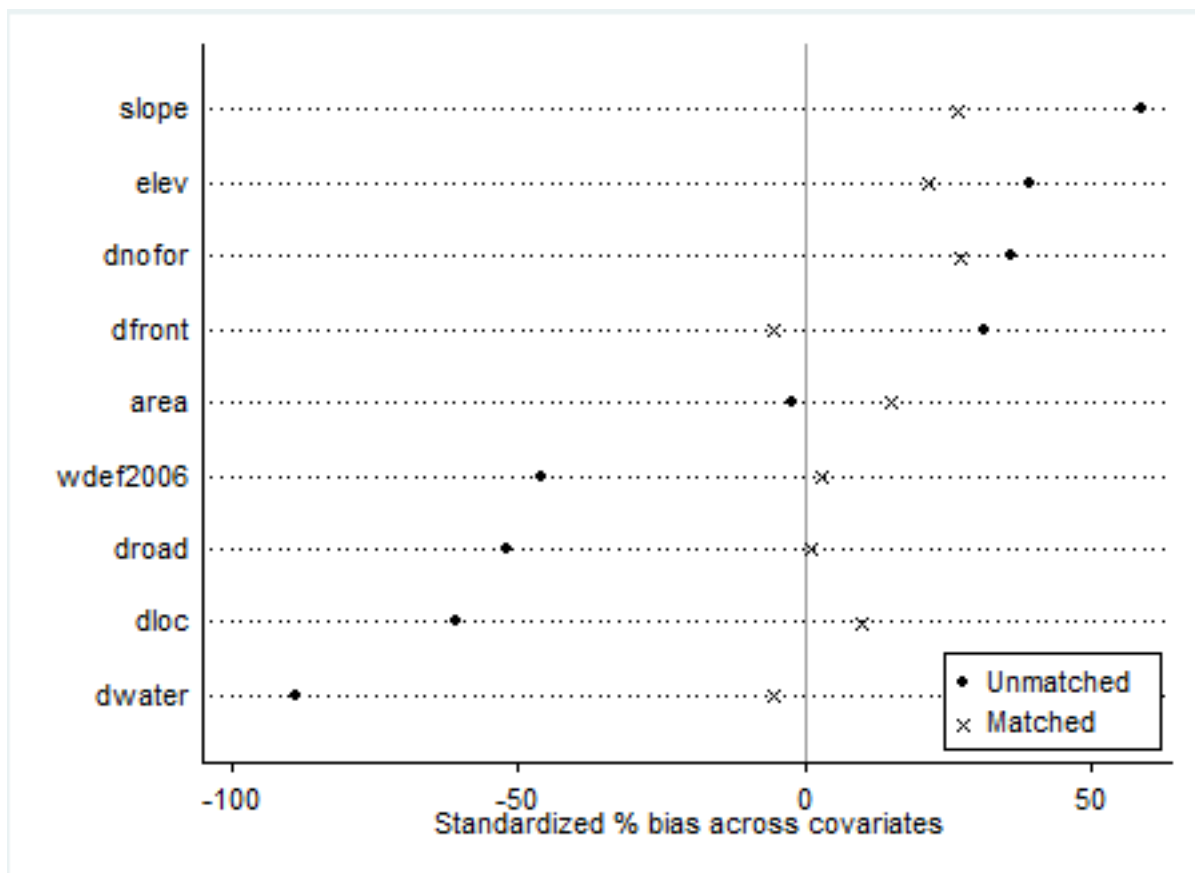
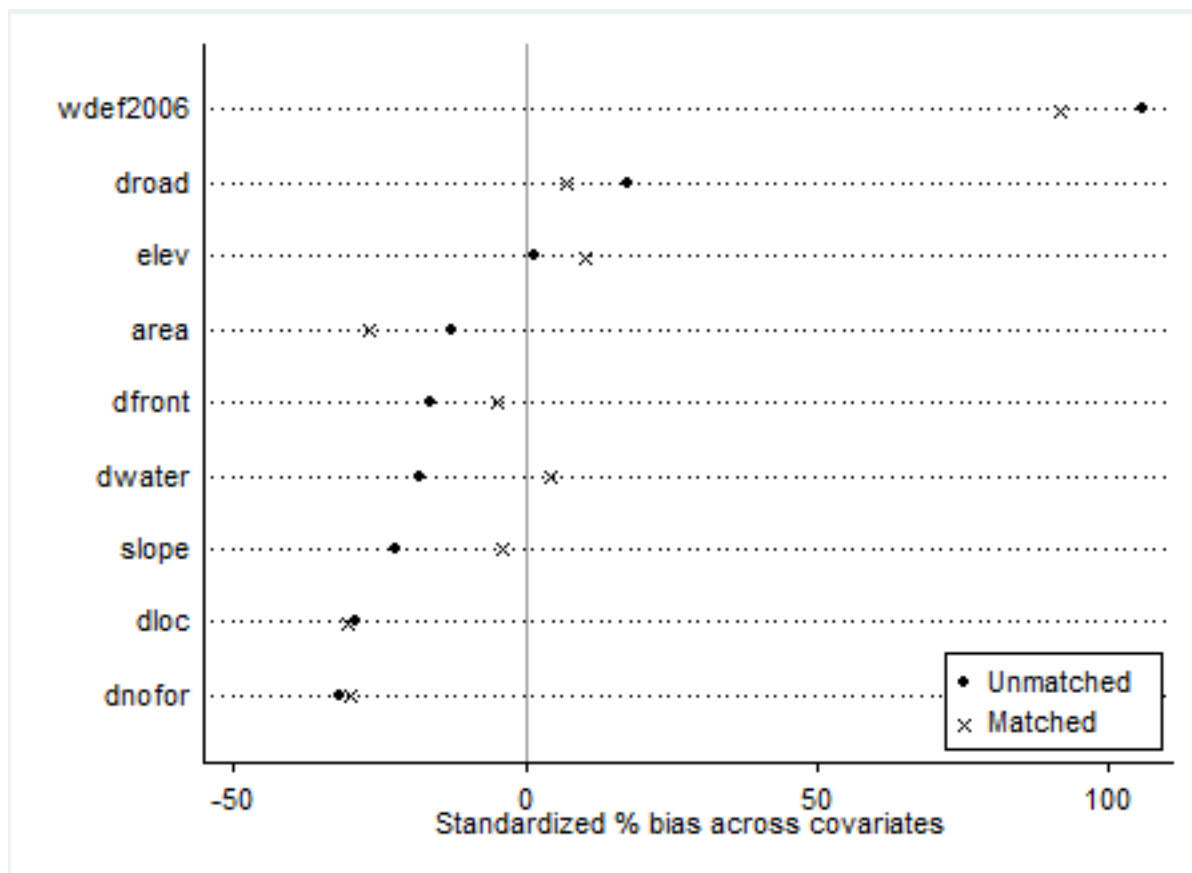


Figure 8: Balancing tests CCB^{Ngos}



E Standard errors clustered at individual level

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

VARIABLES	(1) Deforestation rate	(2) Deforestation rate	(3) Deforestation rate	(4) 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*** (0.0004)	0.0003** (0.0001)	0.0010* (0.0005)	0.0062*** (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

VARIABLES	(1) Area deforested	(2) Area deforested	(3) Area deforested	(4) 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

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