Individual Pay for Collective Performance and Deforestation: Evidence from Brazil*

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February 2023

Abstract

We study Brazil's Bolsa Verde program, which pays extremely poor households for implementing sustainable activities and maintaining forest cover at the communal level. Using difference-in-differences, we find that the program keeps deforestation 22% lower inside treated areas compared to similar untreated areas. The estimated program benefits in terms of emissions reductions are about four times the program costs. Heterogeneous effects across property types suggest that the program provides protection against deforestation pressure from groups other than program recipients. Data on fines and satellite-based alarms point to monitoring and reporting as a mechanism through which the program reduces illegal deforestation.

(***JEL*** I38, O13, Q23, Q28, Q56)

*The project is funded by the Research Council of Norway (project number 230860). We are grateful to Samantha DeMartino for her early insights about the Bolsa Verde program and early data explorations. We thank Andre de Lima for his expert assistance with maps and spatial data. We also thank Stefano Fiorin, Kelsey Jack, Katharine Sims, Mushfiq Mobarak, Eduardo Souza-Rodrigues, Seema Jayachandran and seminar participants at the University of Toronto, University of Wisconsin-Madison, University of Wisconsin-Milwaukee, University of Manchester, the EE NBER Summer Institute 2019, the CEPR/LEAP workshop in development economics 2021, and various other conferences for very helpful comments and discussions. Remaining potential errors and omissions are our own.

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1 Introduction

Over 100 world leaders signed an agreement to end and reverse deforestation by 2030, pledging over US$19 billion to meet that goal in the COP26 meetings in Glasgow.[1] This ambitious target is, however, not a new one: the New York Declaration on Forests in 2014 had a similar commitment, yet the world saw an acceleration in tropical deforestation in the following years.[2] The long-standing policy challenge of how to cost-effectively achieve conservation goals in developing countries, where enforcement mechanisms are weak and financial resources are limited, remains to be resolved.

In this paper, we aim to address this challenge by studying the Amazon rainforest, one of the most important ecosystems in the world. Specifically, we evaluate the effectiveness of Brazil's novel cash transfer program, the Bolsa Verde (BV), which pays rural populations living in extreme poverty conditional on the aggregate forest cover being maintained at 80 percent minimum, in line with the country's Forest Code.[3] Our period of analysis is from 2009 to 2015, covering the few years before the roll-out of the program began in 2011.[4]

[1]https://www.reuters.com/business/environment/over-100-global-leaders-pledge-end-deforestation-by-2030-2021-11-01/

[2]https://www.climatechangenews.com/2021/10/12/countries-failing-protect-forests-7-years-new-york-declaration/

[3]At a global level, programs like Bolsa Verde have not been adopted within Forest Conservation Programs in the world. There are 123 REDD+ projects globally that use conditional cash payments as an incentive mechanism as of September 2021. Of all the 123 projects, there are none which use the combination of collective incentives and individualized payments, - making the BV unique amongst REDD+ projects (see Appendix A for details).

[4]The first households entered the program in November 2011. By August 2012, 62 percent of the receiving areas in our sample were enrolled. In the following three years, the remaining 16, 20 and 2 percent were enrolled. Note that deforestation for, say, 2011 in our data, cover the season August 2011 to August 2012. We match BV recipients to the deforestation data on a monthly basis. The BV program was ceased in 2018 due to lack of federal funding. Note that the conclusions of this study do not change if we

Our analysis is based on all areas eligible for the BV program in the Brazilian Legal Amazon (BLA), where the forests are rich in carbon but the prevalence of poverty is high.[5] Two types of areas are eligible for the BV, namely Sustainable Use Conservation Zones (SUC) and Settlements. SUCs are protected areas created after the 1988 Federal Constitution. Examples include national parks and extractive reserves, which are organized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio). Each area has a manager and there are regular council meetings among residents. Settlements are areas of independent agricultural units that belong to smallholder farmers relocated to the Amazonia under the government-induced migration since the 1970s.[6]

We begin our analysis with a simple difference-in-differences (DD) model, comparing the deforestation rates in areas with BV beneficiaries (*treatment*) and those in similar areas without BV beneficiaries (*control*) before and after the program started. The identification strategy relies on variation in forest loss and program participation over time and across areas. While we do not reject the null of parallel pre-trends, a concern with the DD estimation is potential selection of areas into the BV program based on unobservable characteristics.

To account for potential time-varying confounders, such as differential deforestation pressures facing eventually-receiving and never-enrolled areas, we employ a triple difference (DDD) strategy. Using more disaggregated data (grid cells), we compute the double difference in deforestation rates using cells inside eligible areas (analogous to the area-level analysis) and compare that with the same double difference using outside cells. Our identifying assumption is that, in absence of the treatment, the ratio of deforestation inside vs. outside would follow the same trend at treated and non-treated areas

instead start the analysis in 2006.

[5] As of 2016, municipalities in the BLA had 43.1% of the country's poor, and 6.2% of the extremely poor.

[6] Institutional details of the sub-categories within SUC and Settlements can be found in the Appendix B.

[Gruber, 1994, Olden and Møen, 2022]. By using these outside cells, we should be taking out from the DD estimate any time-varying confounders that is affecting deforestation near eventually receiving zones versus non-receiving zones. Our main result is that the BV reduces deforestation in treated areas by approximately 0.1 to 0.2 percentage points (or 22% of the deforestation in never-treated areas).[7] These results are robust to matching and bias correction for the staggered treatment timing [Callaway and Sant'Anna, 2021].

To identify potential mechanisms, we utilize multiple novel datasets. First, we use information from Brazil's rural property registry (CAR) for private properties to see if the DDD estimates differ by size of the property. We find nil effects of the program on deforestation for smaller properties. For large properties and land that are not registered in the CAR, we find negative and significant impacts of the program. As BV-recipients have low income and are thus more likely to own and manage smaller properties, these results indicate that the overall program effect is not driven by deforestation reductions on the recipients' own properties. Instead, our results imply that one important way for BV beneficiaries to have substantial influence on the level of deforestation is to monitor and report illegal deforestation taking place on nearby large parcels of land. Our finding of no program effects on small properties may be also explained by program participants not being willing to report on their peers, as they perceive them as in-groups, but are willing to report on large landowners (who are rich and out-groups). This finding resonates with Bénabou and Tirole [2003, 2011] who find that monetary incentives can backfire, especially if individuals find it morally unacceptable to be paid for an action that harms their peers.

We investigate the monitoring and reporting channel further by using geo-located data on fines and satellite-based deforestation alarms. Conditional on deforestation taking

[7] These results are consistent with estimates of the effects of other Payments for Environmental Services (PES) programs, which had on average reduced annual deforestation rates by 0.21 percentage points [Wunder et al., 2020, Samii et al., 2015].

place, we find that the number of deforestation related fines increases significantly in BV-treated SUCs. The effect is larger for fines that are far away from where an alarm went off. This finding suggests that the enforcement authorities learn about the illegal deforestation not only through satellite-based alarms, but also some other channels, such as reporting by BV recipients. We cannot however provide evidence of such mechanism working in Settlements.

Our stronger estimated program effect in SUCs compared to Settlements is consistent with what one would expect from the difference in the organisational structure across these communities. SUCs are protected areas, each with a manager who holds regular council meetings with residents. Settlements, in contrast, are areas of independent agricultural units, often without a community management in place. The SUC-managers may reduce the reporting costs for the BV-recipients.

Our paper makes three contributions to the literature. First, it highlights the key novelty of the BV program in terms of its combination of incentives at the individual level and the policy goal defined at the communal level. Typical PES programs are implemented either at individual level - when individuals or households are paid for their actions on land owned by them, or at the collective level - when e.g., contracts are negotiated with groups of neighbouring landholders. Our evidence is consistent with program beneficiaries monitoring land managed by non-program recipients, which in turn keeps deforestation rates low. Such a monitoring channel resembles out-groups monitoring. This stands in contrast to the mutual or community-led monitoring typically addressed by the literature on management of common pool resources (CPR).[8]

[8] Moral hazard has been considered as one of the main challenges for sustainable management of natural resources [Shyamsundar et al., 2005]. Co-management regimes of resources seem the most likely to counter collective action problems in the presence of well-defined property rights and incentives for monitoring at the local level [Berkes et al., 2006]. Empirical work from both the lab and the field in the past few decades has demonstrated numerous examples of successful management of resources by

Second, we contribute to the literature on the challenges of designs of policy mixes that integrate Command-and-Control enforcement policies with PES-based incentives. Even though there are various examples of conservation policies which have worked as policy mixes, the empirical evidence on their effectiveness is still very thin [Wunder et al., 2020]. The administration of the BV program has benefited from leveraging existing regulatory policies, namely the Forest Code and the Bolsa Familia program. The Bolsa Familia (BF) is the world's largest conditional cash transfer program to address poverty and inequality, with an extensive infrastructure that reaches every municipality in Brazil.[9] The BF helped to lower the costs of identifying and paying BV households, while reference to Forest Code made monitoring and reporting more effective.[10] Our back-of-the-envelope calculation estimates total program benefits of USD 415 million, approximately 4 times higher than the program costs.[11]

Finally, our work relates to the literature on improving governance and public goods delivery in developing countries through decentralisation. The key theoretical idea underpinning this strand of research is that agents and middle managers are better informed

communities who self-organize and mutually enforce against exploitative behavior, see e.g., Ostrom [2000] for an overview. More recent research has shown how community-led monitoring [Eisenbarth et al., 2021, Slough et al., 2021] or mutual monitoring [Christensen et al., 2021] can lead to successful CPR management.

[9]The relevant details of the BF program are discussed in section 2.1.

[10]Theoretically, Benthem van and Kerr [2013] show that increasing the scale of Forest Conservation Programs by making entire regions contract for maintaining forest cover above a given threshold increases efficiency.

[11]Many of these policies target deforestation at the potential expense of economic development. Supply chain interventions against deforestation, for example, the Soy Moratorium and zero-deforestation cattle agreements, have been shown to have no average impact on forest cover [Alix-Garcia and Gibbs, 2017]. Policies that penalize violators, such as the blacklisting of heavily-deforesting municipalities, have been shown to reduce deforestation by 35 percent [Assunção and Rocha, 2014] and deforestation caused by increasing agriculture commodity prices by 40 percent [Harding et al., 2021], but limited evidence exists on the economic costs of the policy.

than principals [Aghion and Tirole, 1997].[12] We contribute to this literature by providing suggestive evidence that monetary incentives can mobilize valuable information and allowing for monitoring to be effectively delegated to the program beneficiaries within a context of forest conservation. As Priority Areas are remote, monitoring is expensive for centralized authorities and can be achieved more cost-effectively by incentivizing local citizens.

The rest of this paper is organized as follows: Section 2 provides a brief history of deforestation in the Brazilian Amazon and describes the Bolsa Verde program. Section 3 presents the main data sources and summary statistics. Section 4 outlines the empirical strategy, discusses the estimation results and sources of heterogeneity. Section 5 investigates plausible mechanisms. Section 6 concludes. Tables and figures with a prefix "O" are in the online Appendix.

[12]There is a rich literature which investigates this idea within different contexts. For instance, some studies have investigated the effectiveness of social targeting programs when the task of choosing program beneficiaries was delegated to local organizations or communities [Alderman, 2002, Galasso and Ravallion, 2005]. Another strand of research has documented informational advantages of joint liability lending to the poor compared with traditional forms of lending [Ghatak, 1999, Ghatak and Guinnane, 1999]. This exploits the fact that members of a community know more about one another compared to an outside institution such as a bank. In terms of health services provision, empirical evidence suggests that local controls are effective only when they engage broader community participation to develop a monitoring plan [Banerjee et al., 2004, Björkman and Svensson, 2009]. As discussed above, there is a growing literature on community-led monitoring in forest conservation [Eisenbarth et al., 2021, Slough et al., 2021].

2 Background

2.1 The Bolsa Verde Program: 2011 to 2018

Almost half of Brazil's extremely poor reside in rural areas, which host significant amounts of forest resources [Bindo, 2012].[13] The Bolsa Verde program (BV) has two policy objectives: preserving forests and reducing poverty. It targets the poorest parts of the Brazilian population, the 7.5 million people who live in extreme poverty. A household is eligible for the BV program if it (i) lives in extreme poverty - defined as having per capita monthly income under 77 Brazilian Real (approximately 30USD), and is registered with the CadÚnico (survey used to collect information on low-income families); and (ii) resides in an eligible Priority rural area, which has vegetation level that is in accordance with the Forest Code: at least 80 percent of the land is forested.[14]

The BV program is essentially an extension of the already existing Bolsa Familia (BF), the world's largest conditional cash transfer program (CCT), since a beneficiary of the BV is extremely poor and must already be receiving the *Bolsa Familia*, which has a higher income eligibility threshold. Implemented in 2003, the BF reaches over 50 million people [Erdoğdu and Akar, 2018] and has been praised for contributing towards poverty alleviation and reducing inequality by reaching every municipality in Brazil. With the robust infrastructure the BF has in place, the BV is an additional grant for a subset of BF households who live in eligible areas.[15]

[13]The federal government defines the extreme poverty line to be 77 BRL (approximately 30 USD) of per capita income per month.

[14]The BV was carried out exclusively with resources from the Union General Budget, not related to Norway's International Climate and Forest Initiative or other international initiatives of similar kind. Donations made by the Norwegian government and implemented by the Amazon Fund benefited several regional initiatives in the Amazon, but Bolsa Verde was not one of them. Source: https://g1.globo.com/natureza/noticia/2020/10/26/fundo-amazonia-tem-r-29-bilhoes-em-conta-parados-apos-paralisacao-pelo-governo-bolsonaro-alerta-rede-de-organizacoes.html

[15]Candidates who receive the BF grant have priority to be enrolled for BV. However, those families who

Priority Area Enrolment

First implemented in 2011, the BV was exclusively rolled out within the Brazilian Legal Amazon (BLA), covering an area that is approximately 11.3 million ha.[16] The program has been expanded to the rest of Brazil in 2012, with 64 percent of the areas covered by the program in the north, 26 percent in the northeast; 6 percent in the southeast; and 4 percent in the central-west [Bindo, 2012]. Rural areas are managed by different federal organizations, which nominate areas under their jurisdiction to be eligible for the BV.[17] The Ministry of Environment (MMA) then checks that the forest cover in these areas are in accordance with the Forest Code using satellite data and enlists extremely poor households living in these areas into the BV.

Areas eligible for the BV (Priority Areas) include categories within Sustainable Use Conservation Zones (SUC): Extractive Federal Reserves (RESEX), the Sustainable Development Federal Reserves (RDS), and the National Forests (Flonas); Environmentally Distinctive Agrarian Reform Settlements; as well as territories occupied by extractivists and indigenous groups.[18] SUCs are protected areas created after the 1988 Federal Constitution. Examples include national parks and extractive reserves, which are organized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio). Each area has a manager and there are regular council meetings among residents. Settlements are areas

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quit the BF programme after starting to receive the BV grant do not necessarily lose eligibility for the BV. More details on the BF program can be found in the Appendix E.

[16]Between 1998 and 2000, Brazil's Ministry of the Environment (MMA) identified 900 areas as Priority Areas in terms of biodiversity conservation. For more details on the initiative and details of the selection, see `http://www.mma.gov.br/estruturas/chm/_arquivos/Prioritary_Area_Book.pdf`.

[17]Based on conversations with the MMA and exiting government documents, there were no explicit rules that the authors are aware of that determined which Priority Area gets selected first, or at all, into the BV.

[18]We do not consider territories occupied by riparian, extractivists, quilombolas and other traditional communities in our analysis due to lack of spatial information. In addition, no territories occupied by indigenous people have received Bolsa Verde payments.

of independent agricultural units that belong to smallholder farmers relocated to the Amazonia under the government-induced migration since the 1970s.[19]

Our analysis considers all eligible SUC and Settlements in the BLA with non-zero remaining forests at baseline, an area of approximately 53 million ha. Figure 1, left panel, shows the spatial distribution of BV-eligible zones by category in the BLA, our study area. The right panel depicts the population of these areas in 2010 based on the 2010 Census. On average, Settlements are more populated than conservation zones.

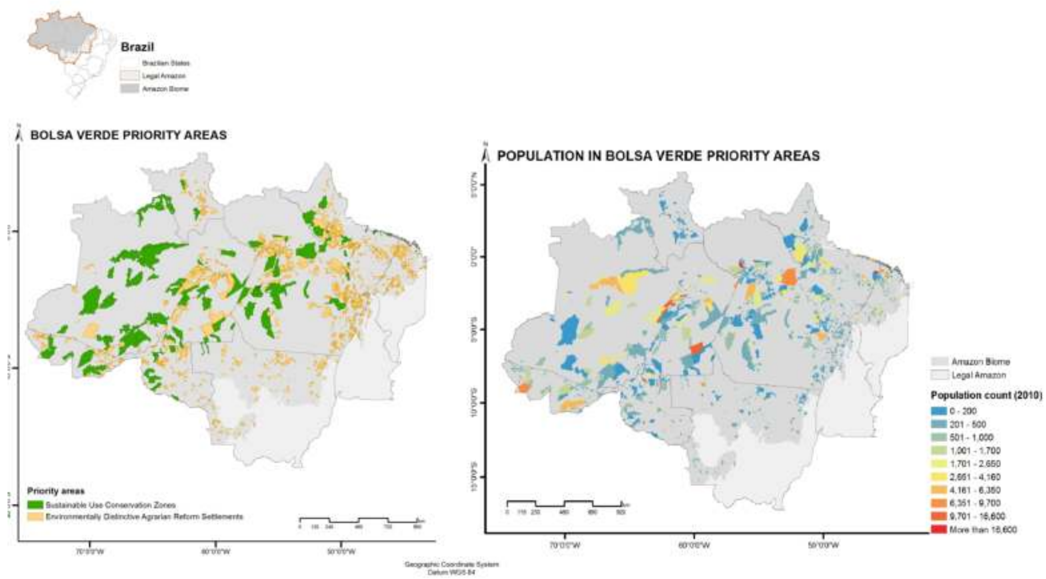


Figure 1: Bolsa Verde Priority Areas by Category and Population

Notes and Source: The figure on the left shows the spatial distribution of SUCs and Settlements in the Legal Amazon. Data for the former come from the MMA and INCRA for Settlements.The figure on the right plots the population in each of the Priority Area using data from the 2010 Census from IBGE.

Selection

Although we are unaware of any explicit selection criteria with which the authorities used to select eligible areas into the program, we check for potential selection by investigating whether pre-BV characteristics predict program enrolment. Table A2 reports

[19]Institutional details of the sub-categories within SUC and Settlements can be found in the Appendix B.

results of regressions of BV enrolment on Priority Area-level characteristics in 2010. Inclusive of all the controls, these characteristics can only predict at most 10% of the likelihood of becoming a BV-receiving Priority Area among SUCs and at most 20% among Settlements (see the R^2 in Table A2). Distances to the nearest city, nearest river, and area deforested are one of the few significant determinants, which we control for in the baseline regressions. Conditional on being enrolled, Table A3 shows that pre-BV area characteristics among SUCs can predict up to 42% the year with which an area becomes enrolled. In particular, SUCs with more area mass, more area deforested and fewer households in 2010 are more likely to be enrolled into the BV later. The result is weaker in Settlements, with pre-BV factors explaining less than 2% of the year of enrolment. In our baseline regressions, we control for all of these significant determinants. Overall, these results suggest that enrolment into the BV is largely unrelated to pre-existing area characteristics.

Household Enrolment

Conditional on living in an eligible Priority Area, households who are extremely poor are eligible to receive the BV. Section C details the administrative process through which eligible households are made aware of and eventually enrol in the program. Benefits are paid quarterly. The quarterly BV payment is 300 Brazilian Real (BRL) per household, or $154 in 2012 U.S. dollars. These benefits account for 13 percent of the average per capita household income in the BLA in 2015.[20] Deforestation alerts based on Deter data and hotspot radars, in combination with sample monitoring, such as periodic visits to families, were used to assess the social and environmental impact and performance of the policy.[21] If the area covered by the program did not comply with the environmental

[20]Brazilian Institute of Geography and Statistics (IBGE), ftp://ftp.ibge.gov.br/Trabalho_e_Rendimento/Pesquisa_Nacional_por_Amostra_de_Domicilios_continua/Renda_domiciliar_per_capita/Renda_domiciliar_per_capita_2015_20160420.pdf.

[21]In addition, the program's environmental monitoring, verifying vegetation cover compliance vis-á-

condition, it would be removed from the program, and the families would have their benefits suspended but would continue to be monitored. The families would receive the benefit again if vegetation recovery were attested in the subsequent monitoring round.

In reality, households have been exiting the program only because of becoming ineligible to the program due to their income surpassing the eligibility threshold, suggesting that forest cover of 80% has never been a binding constraint. This suggests that the BV areas have remained compliant with the program and the program has helped to keep deforestation low within Priority Areas. [22]

2.2 Deforestation in Brazil

The Brazilian Amazon hosts 40 percent of the world's tropical forests. When the local economy relied on extraction of forest resources in the 1960s, Brazil implemented policies that encouraged the occupation of the Amazon. In the 2000s, however, government policies have shifted focus to promoting reductions in deforestation. The deforestation rate in 2014 was approximately 75 percent lower than the average from 1996 to 2005 [Tollefson, 2015]. A popular view attributes this reduction to regulatory efforts and conservation policies of the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA).

The BV may have been motivated by the fact that deforestation in the targeted areas, which are remote and deep into the Amazon biome, has been hard to reduce. Much of the large reductions came in less remote areas. While the level of deforestation in-

vis Forest Code provisions in participation areas, involved methods of monitoring deforestation through orbital tracking via satellite, in partnership with the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), National Institute for Space Research (INPE), and Protection System of the Amazon (SiPAM).

[22] Few areas were removed from the program due to non-compliance with the environmental condition. From our field trip we gathered that most of the families' removal from the program was due to the increase in family income, causing them not to comply with the extreme poverty requirement.

side Priority Areas has always been low relative to the national average, deforestation activities that remain from 2011 are nonetheless non-trivial. In fact, the remaining annual forest loss inside Priority Areas from 2011 to 2015 averages approximately 850 km^2, which is the size of New York City.

Unlike areas outside Priority Areas where much of the deforestation is likely driven by economic activities of large landowners, developments in hydropower [Stickler et al., 2012] and mining [Sonter et al., 2017], deforestation inside can also potentially be attributed to farmers with smallholdings, whose contribution to deforestation has increased by 69 percent [Godar et al., 2014]. In particular, Settlements are likely to be more prone to deforestation by smallholders because settlers are migrant farmers who might deforest as a means to convert forests into other forms of land use, unlike the majority of SUC households who are traditional populations and practice sustainable agriculture and small animal husbandry. This conjecture is consistent with recent evidence showing that deforestation rates accelerated after settlements in the BLA and that the spatial patterns of forest clearing overlap with settlements [Schneider and Peres, 2015].

3 Data

Forests Our main source of data on deforestation is the PRODES project at the Brazilian National Institute of Space Research, which measures the annual loss of primary forests and remaining forest cover in the Legal Amazon.[23] The area covers approximately 500 million ha of land across the northern and western parts of Brazil. The satellite data used in PRODES have spatial resolutions of approximately 30 meters. We process both the

[23]The PRODES project (http://www.obt.inpe.br/prodes/index.php) generates spatial data on deforestation in the Amazon that are used as the official governmental information to guide policy and local actions.

deforestation and remaining forest information from PRODES to generate a grid with 1 km^2 cells.[24] We also assign geo-specific information, such as distances to the nearest city and paved road, to each grid cell based on the centroid.

BV participation We utilize data from the MMA, which provides an exhaustive list of households eligible for the BV program from 2012 to 2015, totaling 31,621 beneficiaries. The list contains information on the names of the representative household member, the Priority Area of residence, and the date of first BV payment or the reason for rejection.[25] To evaluate the success of the BV with respect to its environmental objective, we aggregate these data on eligible households up to the Priority Area level to match with the deforestation data.

Figure A3 shows the BV roll out across eligible areas. Between 2012 and 2015, there were 266 eligible areas (17 percent of the total) receiving the BV payments and 1,539 eligible areas without BV recipients. Participation in the program was rolled out gradually over time.[26] Overall, we have information on 1,805 areas from 2009 to 2015, and the analysis sample covers 42,944,600 ha.[27] Table A1 presents the summary statistics of Priority Areas eligible for BV by receiving status. For each area in the sample, we calculate the

[24]Some cells exhibit inconsistency in remaining forests (increase over time, which is impossible given we focus on primary forests) and we do not use information from these cells (640,837 or 13% of all cells). Figure A2 plots the annual deforestation rates at the cell level from 2009 to 2015.

[25]The list includes households who start receiving the BV from November, 2011, when the program first launched. Since we combine the BV data with deforestation data, we assign deforestation years to each BV recipient. Given that deforestation from PRODES is calculated using the seasonal year starting in August, households who first received BV payments between September 2011 and August 2012 are matched with deforestation in the year 2011.

[26]A total of 166 areas (62 percent of the receiving sample) began receiving the grant by August 2012. Subsequently, 42 additional areas (16 percent of the receiving sample) entered the program by August 2013, 53 new areas (20 percent of the receiving sample) started receiving payments by August 2014, and 5 more areas (2 percent of the receiving sample) entered the program by August 2015.

[27]In the regression analysis, we exclude Project Settlements, a sub-category within Settlements, due to low levels of program participation (only 1.9 percent of all Project Settlements enroll in the BV) and low

number of BV recipients per year. SUCs have 186 recipient households on average, and Settlements have approximately 120 recipient households.

Social registry The CadUnico (single registry), managed by Brazil's Ministry of Social Development (MDS), is a list of all Brazilian citizens who receive any kind of social transfer. CadUnico has detailed demographic and socioeconomic information on all households and its members, allowing us to compute the monthly per capita household income. We geocode the addresses in the registry data and place households into the BV-eligible Priority Areas in our analysis sample.

Registry of rural properties The Brazilian government has established an electronic Rural Environmental Registry (CAR; Cadastro Ambiental Rural) since 2008, covering in principle all rural (private) properties in the entire country.[28] We use data prepared by Bento et al. [2019], which has information on deforestation at each property for each year.[29] We split the properties into four categories (mini, small, medium and large) based on fiscal modules, an official socioeconomic definition of properties. Fiscal modules strongly correlate with size, but vary across the country. [30]

Fines To explore whether the BV encourages participants to monitor illegal activities, we use data on federal fines issued for illegal environmental activities in these areas as outcomes.[31] A subset of these fines are issued against illegal deforestation, while

levels of remaining forests at baseline (less than 50 percent).

[28]The CAR was first implemented in Para and Mato Grosso.

[29]The data are based on a geo-referenced rural property map from CAR and the geo-referenced deforestation data from PRODES used elsewhere in this paper.

[30]For each zone or settlement, we aggregate the sum of deforestation per size category per year. As we only have the property boundaries at the end of the period (around year 2015-2016, depending on when the exact property was registered). Thus, the exercise is based on the assumption that property boundaries have not changed or properties have not merged or split within our sample period.

[31]There is growing literature on the effects of environmental enforcement on deterrence, see, e.g., Shimshack [2014] for through review and Muehlenbachs et al. [2016]. To our knowledge, this literature has focused on the incentives and behaviour of the enforcers, while we examine how delegation of monitoring

the remaining fines are related to all types of illegal environmental activities, such as pollution, infringements of conservation rules, infringements against the administration of conservation zones, illegal acts against wildlife, including hunting and illegal fishing, as well as trafficking of exotic animals.[32]

Carbon To value the forests in terms of carbon, we create a novel dataset by extracting information on carbon stocks from an Above Ground Biomass (AGB) map with 30 meters resolution for the year 2009 (Baccini et al. [2017]). Section F presents more details on our calculations of the carbon data. In 2015, areas eligible for the BV contained 105.8 $\pm$ 30.6 Mg of carbon per ha (1 Mg is 1 metric ton), compared to 87.9 $\pm$ 35.0 Mg in ineligible areas (Figure O1). Among the eligible areas, SUCs had higher carbon stock (127.3 $\pm$ 0.7 Mg per ha) than Settlements (92.6 $\pm$ 36.3 Mg per ha).

4 Identification strategy

4.1 Difference-in-Differences Estimate

Our main outcome of interest is a spot measure of deforestation, expressed as a percentage of lagged remaining forests. We begin with a simple difference-in-differences (DD) model with the Priority Area as the unit of analysis.[33] The first difference compares deforestation in Priority Areas with households receiving the BV before and after the program. This difference is likely to be confounded by other changes taking place in Brazil during this period, so we compute the same difference in deforestation in Priority Areas without BV-receiving households as the control group. Our assumption is that the control areas would be exposed to all the other changes that were affecting the treated

to local communities (poor households) could influence deterrence.

[32]For more details on environmental fines and the source of the data, see http://www.ibama.gov.br/fiscalizacao-ambiental/autuacoes-ambientais.

[33]We add the forest loss across all 1 km^2 grid cells whose centroids lie within a PA.

areas during this period but were not enrolled in the BV because no households fall under the extreme poverty line to qualify.

Identification relies on variation in forest loss and program participation over time and across Priority Areas. The validity of the estimates hinges on the assumption that in absence of the program, deforestation in eventually-receiving areas would follow the same time trends as eligible areas that never received the BV, after controlling for various fixed effects and relevant variables. Since the BV was rolled out to Priority Areas over time, we implement a generalized difference-in-differences (DID) regression model:

$$Deforestation_{zt} = \alpha_0 + \beta BolsaVerde_{zt} + \alpha X_{zt} + \nu_z + \mu_t + \epsilon_{zt} \tag{1}$$

where $Deforestation_{zt}$ is the total area of primary forests deforested in Priority Area z in year t as a percentage share of remaining forests in year $t-1$.[34] $BolsaVerde$ is an indicator variable that equals one if the area z has residing households receiving BV payments in year t. The coefficient of interest is β, which is the DD estimate of the average treatment effect of the BV on deforestation in the treated areas.

We control for X_{zt}, a vector of time-varying, Priority Area-specific factors that could impact deforestation or our measure of deforestation. These factors include the proportion of the Priority Area with clouds and the interaction of lagged remaining forest with distances to the nearest paved road and city. ν_z are Priority Area fixed effects that control for differences in time-invariant unobservables across areas, and μ_t are year fixed effects to control for any year-specific unobservables affecting deforestation in all Priority Areas. Finally, we cluster standard errors at the Priority Area level to control for arbitrary spatial and serial correlation [Abadie et al., 2017].

Table 1 reports the results. We use the full sample of Priority Areas (columns 1 and

[34] Results using the sum of forest loss are consistent with those that use the mean of deforestation across all grid cells in a Priority Area.

Table 1: Difference-in-Differences Estimate of the Impact of the BV Program on Deforestation

Dependent variable	Deforestation as a percentage of lagged remaining forests					
Treatment	Participation (1/0) in Bolsa Verde					
	All zones		SUC		SET	
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment effect	-0.159**	-0.131**	-0.103*	-0.0452	-0.175**	-0.149*
	(0.0642)	(0.0625)	(0.0595)	(0.0317)	(0.0795)	(0.0763)
Covariate controls	No	Yes	No	Yes	No	Yes
Mean of y (untreated units)	0.574	0.574	0.112	0.112	0.714	0.714
Observations	2,968	2,968	602	602	2,366	2,366
R^2	0.007	0.017	0.012	0.147	0.008	0.013

Notes: Dependent variable is the total area deforested in year t as a percentage of remaining forests in year $t-1$. Treatment is a dummy variable that equals one if an area has BV-receiving households and zero otherwise. All specifications include Priority Area fixed effects and year fixed effects. Covariate controls include clouds, and interaction terms between lagged remaining forests and distances to the nearest paved roads and cities. Robust standard errors clustered at the Priority Area level in parentheses.

2) as well as repeating the estimations on two sub-samples: eligible areas that are SUC and those that are Settlements (columns 3-6).[35] The sample split addresses concerns that Priority Areas under different administrative categories may have systematically different drivers for deforestation and respond differently to the BV due to differences in institutional structures. On average, deforestation in receiving areas is 0.31 percent, with the rate being lower in SUCs (0.14 percent) than in Settlements (0.35 percent). The DD estimates of the treatment effect on deforestation range from -0.10 to -0.18 percentage points, or 22% of the deforestation in never-enrolled areas (see Column 2).

We conduct a battery of robustness tests to validate these baseline results. We test for and do not reject the null hypothesis of parallel pre-trends (see Table A4). We check for potential bias from negative weights when using the two-way fixed effects model in a staggered setting and show that the results are robust to using stacked regressions and

[35]In the analysis, we exclude Project Settlements, a subcategory of Settlements, due to low levels of program participation (only 1.9% of all Project Settlements receive BV benefits) In addition, all of the Project Settlements have zero remaining forests as of 2009.

an alternative estimator with correction for this bias [Goodman-Bacon, 2018, Callaway and Sant'Anna, 2021]. We also ensure that the estimation is robust to matching, and we rule out variation in enforcement costs as a confounder (see Section G for more details).

4.2 Impact of the BV over time: Event Study

To understand the time paths of the BV's impact on deforestation, we implement an event study design by repeating the main specification in Table 1 with leads and lags of the treatment:

$$Deforestation_{zt} = \sum_{k=-3}^{4} \delta_k B_{zt-k} + \psi X_{zt} + \tau_z + \gamma_t + u_{zt} \quad (2)$$

where B_{zt} is a binary variable that equals one if area z is a BV-receiving area, and δ_k represents the average difference between receiving and non-receiving areas compared to time period -1, the period immediately before enrollment in the BV. Figure 2 plots the estimated difference between the treatment and control groups before and after the program was implemented. There is not difference between the two groups in the years before. As the program is implemented, deforestation in the treated group gets quickly lower and the difference keeps stable throughout the post period. Given our definition of program enrolment at the area-level being the first year in which a BV payment is received by a resident household, we see the immediate and sharp effect of the program on deforestation.

4.3 Triple Difference Estimate

A concern in our setting is potential selection of Priority Areas into the BV program based on unobservable characteristics. Although we do not reject the parallel trend assumption for the DD, we extend the analysis to further address potential selection. We

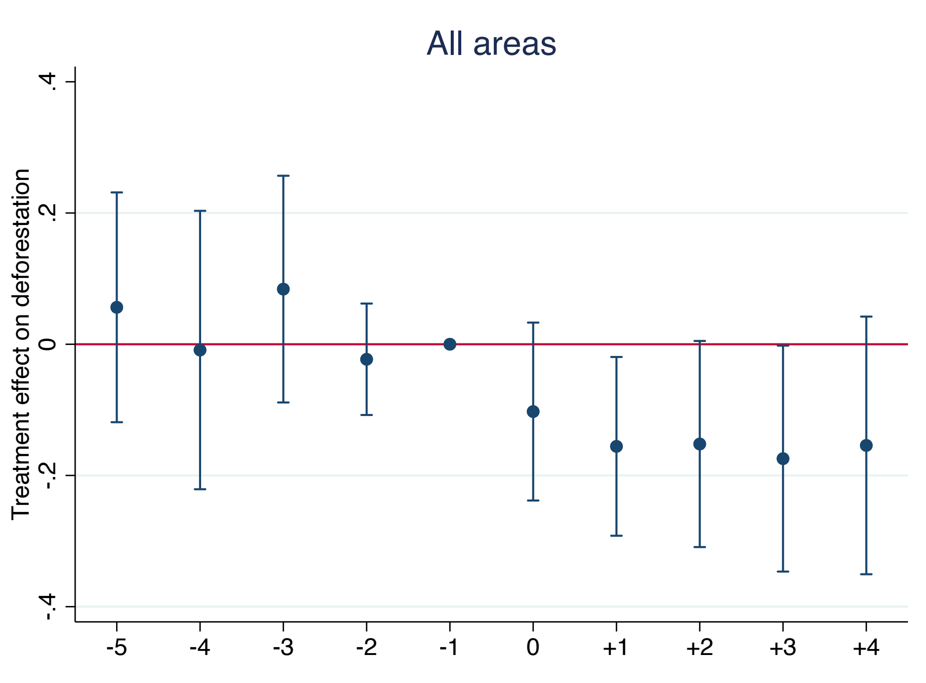


Figure 2: Estimated Changes in Deforestation around the BV enrollment.

Notes: The figure plots the estimated coefficients and confidence intervals of the effect of the BV on deforestation (defined as percentage of lagged remaining forests) in the years before, during, and after the first year of treatment (receiving BV payments). The time period prior to the enrollment in the BV ("-1") is the omitted category. Vertical bands represent 95 percent confidence intervals. The estimates are based on the area-level sample and standard errors are clustered at the area level.

exploit variation at a more disaggregated level, using grid cell data, and implement a triple-difference (DDD) strategy. We compare the double difference inside Priority Areas (at the cell level) with the same double difference outside (the cells that were not exposed to the BV program).

Our identifying assumption is that in absence of BV, the trend in deforestation inside relative to outside would have been the same for the treated and the non-treated areas. Intuitively, the grid cells just outside the border help us taking out from the DD estimate any time-varying confounders at the area level.

Formally, we estimate the DDD model of the following form:

$$
\begin{aligned}
Deforestation_{pzt} = \beta_0 + \beta_1 Inside_{pzt} * Post_{pzt} * Receive_{pzt} \\
+ \beta_2 Inside_{pzt} * Receive_{pzt} + \beta_3 Post_{pzt} * Receive_{pzt} + \\
\beta_4 Inside_{pzt} * Post_{pzt} + \beta_5 Inside_{pzt} + \\
\beta_6 Post_{pzt} + \beta_7 Receive_{pzt} + v_p + \mu_t + \epsilon_{pzt} \quad (3)
\end{aligned}
$$

where $Deforestation_{pzt}$ is the total area of deforestation in year t as a percentage share of remaining forests in year $t-1$ in each grid cell p in Priority Area z. *Inside* is an indicator variable that equals one if the cell is inside any eligible Priority Area, and zero if outside; *Post* is an indicator variable that equals one if the nearest Priority Area to the grid cell is non-BV receiving and the year is 2011 or later, or if the nearest Priority Area is BV-receiving and the year is after the payments have begun; *Receive* is an indicator variable that equals one if the nearest Priority Area to the cell is eventually BV-receiving and zero if the nearest Priority Area never receives the BV. The main parameter of interest is β_1 (triple-difference estimate), and β_2 through β_7 are the estimates of the double interaction terms and linear terms, respectively. Cell and year fixed effects are included in all specifications, with the standard errors clustered at the Priority Area level.

We begin with the full sample but our preferred sample includes only cells lying within 5km on either side of the border of a Priority Area. Conceptually, it is a localized triple difference estimator within a close neighbourhood of the border of an eligible area. Cells that lie just outside and just inside a receiving area should be more similar to each other in absence of the program.

Table 2 reports the triple difference estimates. Columns 1 and 3 show that overall, deforestation inside BV-receiving areas remained lower compared to non-receiving areas (approximately -0.13 to -0.19 percentage points). When distinguishing between SUCs and Settlements, columns 2 and 4 show that the treatment effects are quantitatively similar. Our findings are robust to matching (see Table O9).

Table 2: Triple Difference Estimates of the BV Program on Deforestation

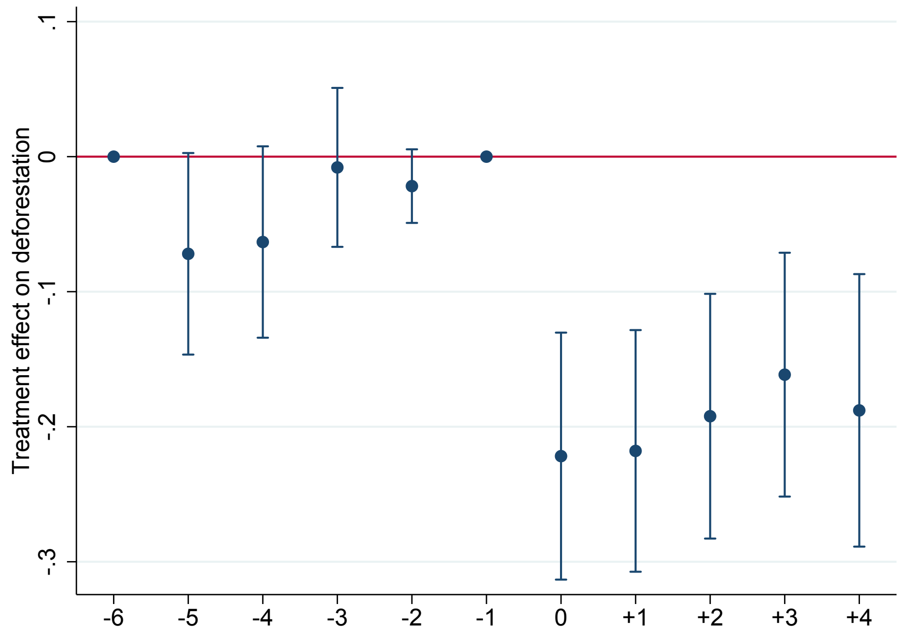
Dependent variable	Deforestation as a percentage of lagged remaining forests			
Sample	All cells		5 km inside or outside	
	(1)	(2)	(3)	(4)
Inside × Receive× Post	-0.131***		-0.187***	
	(0.0471)		(0.0437)	
SUC: Inside × Receive × Post		-0.138***		-0.199***
		(0.0486)		(0.0510)
SET: Inside × Receive × Post		-0.139**		-0.185***
		(0.0671)		(0.0633)
Inside × Post	0.141***		0.203***	
	(0.0447)		(0.0420)	
Receive× Post	0.110**		0.124***	
	(0.0481)		(0.0362)	
SUC: Inside × Post		0.135***		0.193***
		(0.0450)		(0.0483)
SUC: Receive × Post		0.125**		0.149***
		(0.0507)		(0.0398)
SET: Inside × Post		0.171***		0.227***
		(0.0631)		(0.0609)
SET: Receive × Post		0.0847*		0.0938**
		(0.0455)		(0.0372)
Mean of y (untreated inside)	.119	.119	.190	.190
Mean of y (untreated outside)	.295	.295	.579	.579
Observations	15.6 mil	15.6 mil	3,184,795	3,184,795
R^2	0.202	0.202	0.214	0.214

Notes: Dependent variable is deforestation at year t as a percentage share of remaining forests at year $t-1$ in each 1 km^2 grid cell. Each column reports triple difference estimates from separate specifications. Controls include clouds, year and grid cell fixed effects. Robust standard errors clustered at the Priority Area level are in parentheses.

Figure 3 shows the triple-difference estimate using an event-study approach. We do not reject the null of parallel pre-trends for the triple difference. The negative and statistically significant coefficients after the reference period at -1 demonstrates the effect of the BV in keeping deforestation low kicks in relatively quickly at time period 0 and remains so until four years after the program first started. Panel B of Figure 3 presents the triple-difference estimates from distinct specifications by type of Priority Area. The time paths of the estimated effects are quantitatively similar.

We also explore the heterogeneity of the triple difference estimate as a function of income (see Section H for details). Since the BV provides financial incentives for recipients, who are extremely poor, to comply with the program, we would expect the program to have a larger impact in poorer Priority Areas than in wealthier ones. We use micro data from the Brazilian Registry and geocode households for which we have income information and place them into Priority Areas. We show that the DDD estimate is more negative when interacted with a *Poor* dummy (Table O6). This result lends support to our intuition that the program is more effective among recipients for whom the BV payments represent a more substantial boost.

Panel A. All areas



Panel B. SUC or Settlements

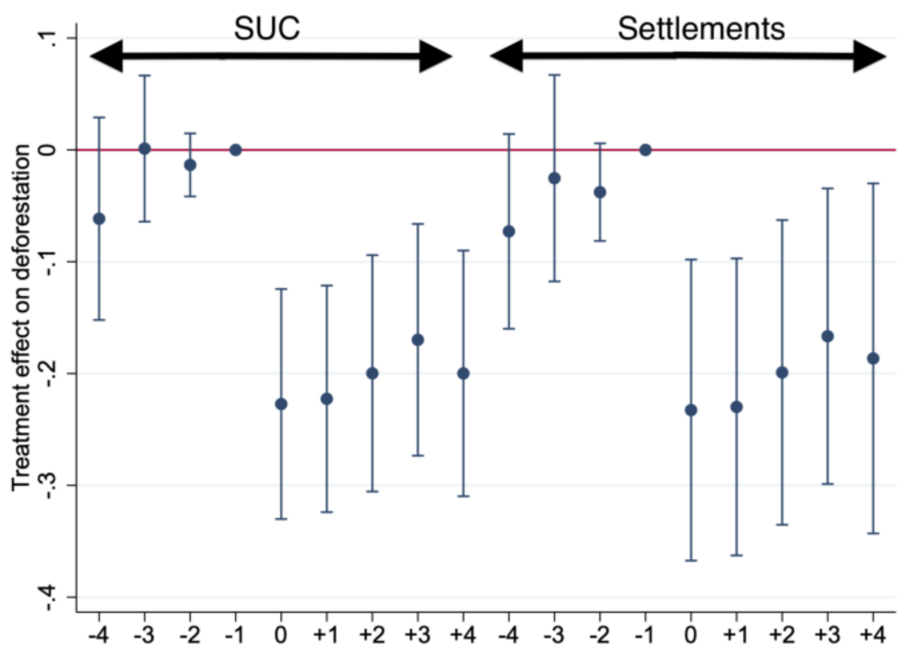


Figure 3: The figures plot the triple-difference event study estimates of the effect of the BV on deforestation. We estimate the program impact for SUCs and Settlements separately (Panel B). The reference period is 2011 for non-receiving cells or one year prior to the year of receiving BV. Bars denote 95% confidence intervals. Estimates are based on the cell-level sample. Standard errors are clustered at the area level.

4.4 Spillovers

A typical concern with conservation programs is that they may displace deforestation to areas that are adjacent [Harding et al., 2021]. If this was the case for the BV program, then the triple difference estimates should overestimate the program impact by picking up the increase in deforestation outside relative to inside the BV-receiving Priority areas. To check if this is the case, we decompose the DDD estimate by estimating a DD using inside cells only and a DD using outside cells only. Table 3 reports the estimates when we use a sample within 5 km on either side of the border.[36]

We note that the DDD estimates are indeed larger: in the preferred 5 km sample, the DDD estimate is -0.187 (Table 2, column 1) while the DD estimate is -0.07 (Table 3, column 1).[37] The larger DDD estimate is partly driven by a bigger increase in deforestation among cells outside receiving Priority Areas relative to cells outside non-receiving areas (Table 3, column 3). This finding is consistent with the spillovers narrative and the DDD estimates for the impact of the BV program would be an overestimate because the BV program pushes deforestation from inside to outside treated Priority Areas.

A competing explanation is that there may be omitted variables that differentially affect the trend in deforestation outside receiving areas relative to outside non-receiving areas (e.g. deforestation pressures). That is, the BV receiving areas face higher deforestation pressures nearby. If this was the case, then the fact that inside these areas, deforestation is lower ex-post shows that the BV program works in terms of keeping the high deforestation pressures outside at bay.

We minimise concerns for spillovers in favor of the competing explanation in a number of ways. First, we show that spillovers are unlikely because deforestation is very low to start with inside these Priority Areas (see Figure A4). The magnitude of the deforestation

[36] Table A5 reports the DD estimations using the whole sample of cells.

[37] Similarly, in the full sample, the DDD estimate is -0.13 while the DD estimate is -0.04 (Table A5).

reduction inside cannot explain the entire increase in deforestation outside. Second, we compare the triple difference estimate that uses only nearby outside cells with an estimate that uses only far away outside cells (Table 4). Even if we implement the triple difference model using only outside cells that are far away from the border (hence should have a smaller impact from spillovers), the estimate remains negative and is of a similar magnitude. Among SUCs, for example, the DDD estimate is at -0.185 when we use outside cells 6 to 8 km from the Priority Area border. This is similar to the -0.189 when we use outside cells that are 0 to 2 km from the border. These findings point to relatively higher deforestation pressure outside of BV-receiving areas, in contrast to spillovers from the policy.

Table 3: Decomposition of Double Difference Estimate of the BV Program

Dependent variable	Deforestation as a percentage of lagged remaining forests			
Sample	Inside cells $\leq$ 5 km		Outside Cells $>$ 5km	
	(1)	(2)	(3)	(4)
Post × Receive	-0.0721*		0.131***	
	(0.0369)		(0.0369)	
SUC: Post × Receive		-0.0716*		0.160***
		(0.0372)		(0.0405)
SET: Post × Receive		-0.0732*		0.0956**
		(0.0402)		(0.0376)
Mean of y (untreated)	0.190	0.190	0.579	0.579
Observations	1,398,072	1,398,072	1,786,723	1,786,723
R^2	0.051	0.051	0.026	0.026

Notes: Dependent variable is the total area deforested in year t as a percentage of remaining forests in year $t-1$. Treatment is a dummy variable that equals one if the grid cell lies in a Priority Area that has BV-receiving households and zero otherwise. All specifications include cell fixed effects and year fixed effects. Covariate controls include clouds. Robust standard errors clustered at the Priority Area level in parentheses.

The results among Settlements, however, are more suggestive of spillovers. The DDD estimate is -0.164 when we use outside cells that are 6 to 8 km from the border. When using outside cells that are just 0 to 2 km from the border, the DDD estimate is -0.207. Since the former is about 20 percent smaller than the latter, we do not rule out the possibility that deforestation may have been pushed some deforestation from inside the

BV-receiving Settlements to just outside these areas.

Table 4: Triple Difference Estimate with Different Outside Cells

Dependent variable	Deforestation as a percentage of lagged remaining forests						
Type of outside cells	All	0-2 km	2-4 km	4-6 km	6-8 km	8-10 km	>10 km
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SUC: Inside × Post × Receive	-0.138***	-0.189***	-0.156***	-0.160***	-0.185***	-0.162***	-0.130**
	(0.0486)	(0.0490)	(0.0426)	(0.0463)	(0.0425)	(0.0466)	(0.0593)
SET: Inside × Post × Receive	-0.139**	-0.207***	-0.107	-0.123*	-0.164**	-0.142*	-0.139*
	(0.0671)	(0.0613)	(0.0671)	(0.0652)	(0.0718)	(0.0737)	(0.0749)
Constant	0.286***	0.201***	0.172***	0.163***	0.160***	0.154***	0.231***
	(0.0292)	(0.0103)	(0.00987)	(0.00988)	(0.0101)	(0.0103)	(0.0341)
Mean of y (untreated units)	.270	.262	.218	.202	.193	.184	.201
Observations	15.6 mil	3,902,411	3,846,985	3,802,086	3,755,404	3,717,779	12.4 mil
R^2	0.202	0.218	0.219	0.222	0.217	0.220	0.197

Notes: Dependent variable is the total area deforested in year t as a percentage of remaining forests in year $t-1$. Treatment is a dummy variable that equals one if the grid cell lies in a Priority Area that has BV-receiving households and zero otherwise. . All specifications include grid cell fixed effects and year fixed effects. Covariate controls include clouds. Robust standard errors clustered at the Priority Area level in parentheses.

5 Mechanisms

5.1 Analytical Framework

With multiple actors of deforestation operating in Priority Areas, one objective of the study is to understand the types of deforestation that respond to the BV. In this section, we discuss and empirically test some of the main potential mechanisms behind our estimated impact of the program on keeping deforestation low in treated areas.

Agents changing their deforestation behaviour

In our analysis, we define enrolment at the area level using the first year in which we observe a resident household receiving the BV payment. The program participant receives the BV payment, if and only if, the aggregate forest cover is kept at or above 80% of the total land area. Maintaining the high level of forest cover in the Priority Area depends on the deforestation activities of the BV participant and the level of deforestation by everyone else. This means the BV participants have two decisions to make: i) the amount of forest to cut, if any, and ii) the amount of effort to monitor and report others' deforestation, if any.

Since the BV participants are extremely poor households, the change in their individual deforestation behaviour cannot substantially change the overall level of forest cover in the area. In addition, some households have already been engaging in sustainability practices and seeing little scope for improving their behaviours, such as in the SUCs. Therefore, it would be expected that the BV participants would not have incentives to change their deforestation behaviour, and instead would choose to exert efforts in observing and reporting acts of illegal deforestation.

These mechanisms would manifest more significantly in those priority areas where the main actors of deforestation are non-BV beneficiaries, for example, on large pieces of land. These considerations are also conditional on the fact that there is substantial level of deforestation happening in the area. We empirically test for the validity of this mechanism by exploring the heterogeneity of the estimated program impact by property type (see Section 5.2.

Political economy channels

The impact of the BV program on deforestation can be also manifested through the political economy channels. As federal agencies nominate areas under their jurisdiction for enrolment, and as one of the objectives of the program is poverty alleviation, the nominating agencies might have incentives to maintain their jurisdictions' eligibility to the program. This could mean allocating more resources toward enforcement, helping to keep deforestation low in enrolled areas and leading to the positive effect of the BV program. Due to data limitations on resource allocation from Federal agencies to each Priority Area, we do not empirically test for and thus remain open to the possibility of this channel as an explanation for our results.

Monitoring and reporting

A third plausible channel is that the BV works by providing incentives for participants to monitor and report illegal deforestation. In large areas, monitoring costs will be particularly high for poor households due to at least two reasons: i) they do not have appropriate resources such as vehicles to patrol large areas of land; and ii) they have high opportunity cost of time as they are also engaging in subsistence agriculture. In implementing monitoring activity, the BV beneficiary would choose to observe areas which are the most prone to illegal deforestation to increase their returns to their monitoring activity. The key idea is that this kind of monitoring activity is cheaper for agents than for the principal as Priority Areas are remote and locals may have information on where and by whom illegal deforestation is undertaken. We empirically test for this mechanism in Section 5.2 using spatial data on fines and satellite alarms.

Anecdotal evidence suggests that the majority of reporting took place through informal channels such as passing information to the manager or other ICMBio (agency responsible for protected areas) employees. The effectiveness of the monitoring and reporting channel is likely influenced by the social structure and interactions within communities. In the SUCs, monetary rewards are likely to be strongly aligned with incentives to monitor and report compared with Settlements (see Appendix D for more details of how the BV beneficiaries report and differences in reporting in the SUCs versus Settlements).

5.2 Empirical tests

5.2.1 Program Beneficiaries: Program Intensity

In this section, we explore meaningful sources of heterogeneity in the BV's effects in keeping deforestation low in treated Priority Areas. The first is program intensity, the idea that the program's effects on deforestation depend on the number of beneficiaries in a region. There are two competing forces at work. With a larger number of beneficiaries per Priority Area, free riding amongst BV-participants may arise. At the same time, more BV participants per area would strengthen both the prevention and monitoring/reporting channels outlined in Section 5.1.

To determine which effect dominates, we repeat the estimation of Equation (3) by splitting the sample according to the number of beneficiaries per km^2 in a given Priority Area in year t. Table A6 reports the estimates. Among areas with fewer than 1 recipient per km^2 (columns 1 to 4), the magnitude of the coefficient in both SUCs and Settlements is about -0.2 percentage points.[38] As we narrow our focus to Settlements with at least 5 recipients per km^2, the magnitude of the DDD estimate declines, and is about halved, to -0.11 percentage points, when the Settlements have more than 10 recipients per km^2 (column 7).[39]

Overall, the falling effect size in density of recipients suggests that free-riding may be a concern and it may even dominate the monitoring channel in Settlements.

5.2.2 Property Type

As discussed in Section 5.1, we consider whether BV recipients reduce their own deforestation or monitor their areas of residence for illegal deforestation activities conducted by others, for example logging companies or large-scale farmers. BV recipients have low income, otherwise they would not have been eligible for the program, and hence they are likely to live on smaller properties. Thus, we use the CAR property registry to categorize our grid cells. Specifically, we split the baseline sample into cells that lie in areas dominated by either micro, small, medium or large properties or by non-CAR areas.[40]

[38]The maximum number of beneficiaries per km^2 in SUCs is 1.

[39]The highest number of recipients per km^2 in Settlements is 29.

[40]The CAR property size categories are based on the Brazilian agrarian legal measure, the fiscal module (FM), instituted by Law No. 6,746/1979 (13). The classification system defines four categories: micro (<1 FM), small (1-4 FMs), medium (4-15 FMs) and large (> 15 FMs). The actual size of an FM is municipality-specific. In this study, the municipalities covered have FMs ranging from 5 to 100 hectares.

Table 5 shows the results. We do not find that the BV reduces deforestation on micro, small or medium private properties; the coefficients for micro and small is either positive or small and in any case statistically insignificant. In contrast, the coefficients for large and Non-CAR areas are negative and significant. This result holds up when we split the DDD coefficient by type of Priority Area (see Table A7). For micro and small, the coefficients are insignificant for both SUCs and Settlements but vary in sign and magnitude, whereas there is a significant negative effect also for medium in SUCs.

Overall, these results are consistent with the program motivating recipients to hinder illegal deforestation likely committed by others. This points towards monitoring and reporting as the relevant channel.

Table 5: Impacts of Program by Property Type (CAR Registry)

Dependent variable	Deforestation as a percentage of lagged remaining forests				
Type of property	Micro	Small	Medium	Large	Non CAR
	(1)	(2)	(3)	(4)	(5)
Inside × Receive × Post	0.360	-0.164	-0.211	-0.355***	-0.111***
	(1.030)	(0.443)	(0.245)	(0.0684)	(0.0411)
Inside × Post	-1.102	0.680*	0.197	0.325***	0.120***
	(0.872)	(0.371)	(0.197)	(0.0586)	(0.0391)
Receive × Post	0.0934	0.120	0.237***	0.173***	0.101**
	(0.275)	(0.145)	(0.0797)	(0.0617)	(0.0435)
Constant	1.017***	0.909***	0.857***	0.530***	0.177***
	(0.269)	(0.261)	(0.140)	(0.0545)	(0.0261)
Mean of y (untreated)	1.05	1.10	.658	.390	.149
Observations	325,187	254,493	100,489	56,594	14.7 mil
R^2	0.242	0.254	0.251	0.258	0.188

Notes: Dependent variable is the average deforestation at the property level (in km^2) in year t as a percent share of the remaining forests in year $t-1$. column 5 uses deforestation at the cell level as the dependent variable. The table reports triple difference estimates on separate specifications. Robust standard errors clustered at the Priority Area level are in parentheses.

5.2.3 Monitoring and Fines

We now use our rich spatial dataset on fines and alarms to empirically gauge the validity of the reporting mechanism. We start by calculating the total number of fines that were issued inside the administrative boundaries of each BV-eligible Priority Area in a given year. We then distinguish between fines issued for illegal deforestation, I^{df}, and those that are issued for other illegal environmental acts, I^{o}. Finally, for each fine, we calculate the distance to the nearest alarm and distinguish between fines that overlap and those that do not overlap with an alarm by defining various distance thresholds.[41]

Figure O7 illustrates the spatial distribution of DETER alarms and fines issued for illegal deforestation in the Legal Amazon in 2015. While there is much spatial overlap between DETER alarms and fines, we also observe fines that are far away from alarms. This suggests that enforcement officials detect illegal deforestation activities from sources other than alarms, such as reports from locals.

To formalize the argument, we extend our discussion in section 5.1 by noting that for a committed crime to result in actual penalties and fines, three conditions need to be met: (i) the offence has to happen; (ii), the offence has to be detected; and (iii) the offence has to be reported; and (iv) a report has to lead to fine. The (iv) is up to the bureaucrats. Importantly, the BV program can affect the likelihood of all three conditions. While the BV program may reduce deforestation and hence the likelihood of (i), the program strengthens (ii) and (iii). Thus, the overall effect of the BV on the number of fines is a-priori ambiguous. We test whether the BV increases the number of fines with the following specification:

$$I^{i}_{pzt} = \alpha_0 + \gamma BolsaVerde_{pzt} + \alpha_1 Deforestation_{pzt} + \alpha_2 X_{pzt} + \upsilon_p + \mu_t + \epsilon_{pzt} \tag{4}$$

where $I^{i}_{pzt}, i = df, o$ denote fines issued for illegal deforestation or other environmental offences respectively; and the other variables are defined in the same way as before. Our

[41]The typical source of information for the location of illegal deforestation is the DETER or the Real Time System for Detection of Deforestation, a monitoring system launched by the Brazilian government in 2004 to identify deforestation hot spots in near real time using satellite images.The DETER system locates forest cover changes down to 25 ha and at a frequency of 15 days.

parameter of interest is γ, which measures the association between the BV program and fines, conditional on deforestation. We restrict the sample to include only cells with non-zero deforestation in a given year (a crime must have been committed). We use the log of the number of fines as the dependent variable, using only fines that do not overlap with alarms - defined as fines that are at least 5 km from the nearest alarm.[42]

Table 6 reports the results. We find an increase in deforestation-related fines in BV-receiving SUCs but not in Settlements (columns 4-6). Similarly, for spillovers to other fines, we find a positive (but smaller) coefficient for SUCs and a small insignificant coefficient for Settlements.[43] Overall, the finding that participation in BV is associated with more fines that do not overlap with alarms is consistent with BV recipients monitoring the areas and reporting illegal deforestation to the authorities.

The results regarding SUCs vis-á-vis Settlements may be explained by the institutional differences between the two types of areas. SUCs have managers and community councils, while Settlements often do not have community management in place. The direct communication of the managers with the BV participants in the SUCs may enhance trust in the management and facilitates the process of BV participants reporting illegal deforestation to the manager. If we view trust between a manager and BV participants in the SUCs as a proxy for congruent preferences, then these results are consistent with the theoretical insights of Aghion and Tirole [1997] that organizations are likely to decentralize

[42]We use the inverse hyperbolic sine function when implementing the log transformation so that we do not omit cell-year observations with zero fines from the analysis. Our results are robust to using 1km as the distance threshold, and to the use of non-overlapping fines (see Section J for details).

[43]For non-deforestation crimes, there may be spillovers from the BV program in the form that non-deforestation actors react to the deforestation "regulation" or in the form of detection and enforcement. Shimshack and Ward [2005], for instance, provides an example of the spillover effect from regulation policies when water polluters who are not fined react to fines issued on other actors. Other studies provide evidence in support of the spillovers from the prevention mechanism (e.g., Andrade and Chagas [2016] and Decker and Pope [2005]).

if the principal and agent have congruent preferences. [44]

Table 6: Triple Difference Estimated Impact of the BV Program on Fines

Dependent variable	Log of Non-overlapping fines (>5 km from nearest alarm)					
Type of fines	All	Deforestation	Other	All	Deforestation	Other
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × Dreceiv=1 × Post	0.0117	0.00959	0.00351			
	(0.00979)	(0.00883)	(0.00294)			
SUC: Inside × Receive × Post				0.0259***	0.0194**	0.00851*
				(0.00939)	(0.00793)	(0.00476)
SET: Inside × Receive × Post				-0.00172	0.000196	-0.00143
				(0.0160)	(0.0152)	(0.00202)
Constant	-0.00236	-0.00193	-0.000313	-0.00280	-0.00224	-0.000480
	(0.00567)	(0.00587)	(0.000650)	(0.00554)	(0.00575)	(0.000642)
Mean of y	.004	.004	.000	.004	.004	.000
Observations	86,293	86,293	86,293	86,293	86,293	86,293
R^2	0.382	0.377	0.392	0.382	0.377	0.392

Notes: The dependent variable is the log of the number of non-overlapping fines. The treatment is a dummy variable that equals one if a grid cell lies inside a Priority Area that has BV-receiving households, and zero otherwise. All specifications include grid-cell fixed effects and year fixed effects. Covariate controls include cloud cover. Robust standard errors clustered at the Priority Area level in parentheses.

6 Conclusion

At the 2021 COP26, Germany, the Netherlands, Norway, US, UK and 17 private funders committed to deliver at least US$1.7 billion of financing to indigenous peoples and local communities over the next five years. The aim is to support the advancement of their "tenure rights and greater recognition and rewards for their role as guardians of forests and nature."[45] Our paper supports that local populations can be mobilized for conservation. In particular, paying the poor to monitor without necessarily paying resource owners to conserve can be effective in containing deforestation.

[44]The same interpretation of trust was given by Bloom et al. [2012] who find that firms are more decentralized when located in regions that are judged by those in the headquarters location to contain more trustworthy people. In addition, as the empirical literature on this subject has mostly focused on why private-sector firms decentralize, our analysis provides consistent evidence within a novel context.

[45]https://www.fordfoundation.org/the-latest/news/governments-and-private-funders-announce-historic-us-17-billion-pledge-at-cop26-in-support-of-indigenous-peoples-and-local-communities/

We arrive at this conclusion by evaluating Brazil's novel cash transfer program, the Bolsa Verde, which pays extremely poor families for forest conservation at the regional level. Using both difference-in-differences and triple difference models, we show that the BV program keeps deforestation low in treated areas. We rule out spillovers from sustainable use conservation zones (SUCs) and document instead high general deforestation pressure outside of treated areas. For Settlements, we cannot rule out that some spillovers from treated to non-treated areas just outside take place. However, our results on a negative effect of the program on deforestation are robust to matching and various specifications. We also find that the treatment effect is larger in areas with lower average income.

We highlight monitoring and reporting as one of the plausible mechanisms behind these results. Our analysis use data from the rural registry on private properties to show that the program holds back deforestation on large and non-private properties rather than on small properties. This suggests that the program effect is not driven by the BV recipients deforesting less on their own land but rather by curbing deforestation committed by non-recipients. We also exploit data on fines and deforestation alarms to show that the number of fines against illegal deforestation, specifically those that are far away from alarms, increases in SUCs treated with BV recipients.

Using our area-level estimates, we perform a back-of-the-envelope calculation of the benefits and costs of the program from the perspective of the Brazilian government.[46] Section K in the Appendix provides more details. Valuing CO_2 at 50 USD per tonne (in 2020 prices), program benefits in SUCs are approximately USD 6 million per area or USD 262 million for all the 43 SUCs in our sample. The equivalent on Settlements are approximately USD 0.79 million per area or USD 153 million in total. The program

[46]We use our DD estimates to perform the calculations as the BV program is administered at the Priority Area level; we thus analyse the cost and benefits at the same unit of analysis. The DDD estimates are based on analysis at the cell level, but we do not observe the number of beneficiaries at the cell level.

costs 300 BRL (USD154) per recipient household per quarter, or USD616 per year. Since our analysis sample has 31,621 beneficiaries, the cost of the program between 2011 and 2015 is USD 97.5 million.[47] The estimated total program benefits of USD 415 million are approximately 4 times the program costs.

It is worth highlighting that the costs calculated in this way only take into account the quarterly cash payment to each beneficiary household and is likely a lower bound estimate. Moreover, the current study does not evaluate the impact of the BV payments on the wellbeing of recipient households, such as through an improvement in the quality of goods consumed. Neither do we explore the distributional impact of the BV payments within and across households. These are important areas for future research.

An important caveat of the paper is that the BV has been implemented on the back of the Bolsa Familia, a large-scale existing policy. A similar design may not work in other settings with a less sophisticated enforcement and administrative environment, which are typical characteristics of settings that the majority of PES programs are in. Moreover, deforestation in Brazil, like in many other tropical countries, is primarily caused by deforestation activities of large landholders. Many proponents of PES programs would argue that policy action should move into the high-pressure areas and thus available funding should be required to pay the higher voluntary conservation payments to high cost landholders [Wunder et al., 2020]. However, this would substantially raise the costs of the PES programs in developing countries.

Our analysis of the BV program suggests a feasible alternative - provision of conservation payments to extremely poor households, who can ensure monitoring and enforcement. Our study shows that such a PES program can help insulate remote forests against external pressure.

[47]This cost measure abstracts away from administrative cost of the program that are unobserved by us. Therefore, the actual costs associated with implementing the program are likely higher than only the payment to each beneficiary.

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A Tables and Figures

Table A1: Summary Statistics: Receiving and Non-Receiving Priority Areas

Administrative categories		Mean # of BV beneficiaries	Number of areas		Mean % of remaining forests in 2008		Mean Area (1000 hectare)	
		Receiving	Receiving	Non - receiving	Receiving	Non - receiving	Receiving	Non - receiving
SUC	FLONA	96.462	13	17	0.989	0.980	448.208	423.888
		(162.455)	[0.433]	[0.567]	(0.010)	(0.031)	(312.305)	(375.094)
	RESEX	218.69	29	11	0.887	0.936	304.876	167.280
		(367.860)	[0.725]	0.275	(0.238)	(0.058)	(255.943)	(93.980)
	RDS	202	1	16	0.977	0.949	57.6	584.519
		-	[0.059]	0.9412	-	(0.065)	-	(723.537)
Settlements	PA	42.269	26	1351	0.436	0.310	54.877	7.377
		(63.086)	[0.019]	0.9811	(0.380)	(0.284)	(137.726)	(14.505)
	PAE	119.689	186	59	0.894	0.862	29.176	37.860
		(208.374)	[0.759]	0.2408	(0.110)	(0.186)	(102.916)	(105.821)
	PAF	31.333	3	4	0.955	0.976	43.167	33.7
		(13.650)	[0.429]	0.5714	(0.030)	(0.027)	(53.860)	(10.079)
	PDS	76.625	8	81	0.856	0.789	31.988	26.547
		(59.678)	[0.090]	0.9101	(0.141)	(0.238)	(38.249)	(59.318)

Notes: The table presents summary statistics of all BV-eligible Priority Areas inside the PRODES mapping area in the Legal Amazon region. We exclude areas with zero remaining forests in 2009, the first year of the analysis. Only the following categories within SUC and Settlements are eligible for BV: Extractive Federal Reserves (RESEX), Sustainable Development Federal Reserves (RDS), National Forests (Flonas), Settlement Projects (PA), Agro Extractivist Settlement Project (PAE), Forest Settlement Project (PAF), and Sustainable Development Project (PDS). Percentage of areas by receiving status are in brackets. Standard deviation are in parentheses.

Table A2: BV Program Enrolment and Pre-Program Characteristics

Dependent variable	Enrollment (1/0) in the Bolsa Verde					
	SUC			Settlement		
	(1)	(2)	(3)	(4)	(5)	(6)
Area deforested	-0.0167	-0.0155	-0.0255*	-0.0579**	-0.0678***	-0.0511***
	(0.0131)	(0.0119)	(0.0149)	(0.0239)	(0.0235)	(0.0160)
Percent of land with remaining forests	-0.00174	-0.0000837	-0.000540	0.00108	0.00228	0.00333**
	(0.00291)	(0.00343)	(0.00377)	(0.00154)	(0.00144)	(0.00135)
Land area		-0.0000146	-0.0000189*		-0.0000327	0.0000200
		(0.0000111)	(0.0000110)		(0.0000388)	(0.0000367)
Number of households		0.000259	0.000254		0.000509***	0.000402***
		(0.000253)	(0.000238)		(0.000111)	(0.0000969)
Distance to nearest city			-0.00000144			-0.00000504***
			(0.00000189)			(0.00000121)
Distance to nearest river			0.00000640*			-0.00000497**
			(0.00000339)			(0.00000213)
Distance to nearest highway			0.00000132*			0.00000114
			(0.000000674)			(0.00000114)
Constant	0.654**	0.525*	0.459	0.530***	0.393***	0.514***
	(0.253)	(0.294)	(0.292)	(0.117)	(0.112)	(0.119)
Mean of y						
Observations	85	85	85	338	338	338
R_squared	0.009	0.034	0.098	0.031	0.113	0.209
F-statistic, joint significance	0.86	0.97	1.61	3.19	8.01	17.75
p-value, joint significance	0.43	0.43	0.15	0.05	0.00	0.00

Notes: Table regressions binary variable equal to 1 indicating eventual enrolment into the BV from 2011 on Priority Area-level factors in 2010, before the launch of the program. We split the sample into SUCs and Settlements. Standard errors are clustered at the municipality level.

Table A3: Year of BV Program Enrolment and Pre-Program Characteristics

Dependent variable	Year of Enrolment in the Bolsa Verde					
	SUC			Settlement		
	(1)	(2)	(3)	(4)	(5)	(6)
Area deforested	0.184*	0.289***	0.277***	-0.128	-0.221	-0.196
	(0.0980)	(0.0765)	(0.0728)	(0.170)	(0.194)	(0.204)
Percent of land with remaining forests	-0.00254	-0.00959***	-0.00505	0.00307	0.00331	0.00447
	(0.00381)	(0.00237)	(0.00423)	(0.00410)	(0.00484)	(0.00481)
Land area		0.000102***	0.000119***		0.0000239	0.000122*
		(0.0000172)	(0.0000284)		(0.0000835)	(0.0000629)
Number of households		-0.00121***	-0.00138***		0.000224	0.000131
		(0.000291)	(0.000356)		(0.000214)	(0.000196)
Distance to nearest city			-0.00000433			-0.00000657
			(0.00000338)			(0.00000538)
Distance to nearest river			-0.00000513			-0.00000637
			(0.00000344)			(0.00000654)
Distance to nearest highway			-0.000000968			-0.00000133
			(0.000000890)			(0.00000353)
Constant	2011.6***	2012.0***	2012.1***	2011.4***	2011.4***	2011.6***
	(0.311)	(0.171)	(0.173)	(0.293)	(0.289)	(0.287)
Observations	42	42	42	196	196	196
R_squared	0.095	0.364	0.426	0.007	0.016	0.055
F-statistic, joint significance	1.87	24.18	8.21	0.47	0.81	1.15
p-value, joint significance	0.17	0.00	0.00	0.63	0.53	0.35

Notes: Table regressions binary variable equal to 1 indicating eventual enrolment into the BV from 2011 on Priority Area-level factors in 2010, before the launch of the program. We split the sample into SUCs and Settlements. Standard errors are clustered at the municipality level.

Table A4: Testing the Parallel Trends Assumption in Difference-in-Differences Estimation

Dependent variable	Deforestation as a percentage of lagged remaining forests					
	No controls			With controls		
	All	SUC	Settlements	All	SUC	Settlements
	(1)	(2)	(3)	(4)	(5)	(6)
BV × Yr_{t-5}	0.109		0.124	0.0563		0.0727
	(0.0916)		(0.113)	(0.0891)		(0.106)
BV × Yr_{t-4}	0.0294	0.0389	0.0404	-0.00883	-0.0521	0.00487
	(0.110)	(0.0743)	(0.126)	(0.108)	(0.0386)	(0.121)
BV × Yr_{t-3}	0.102	0.384	0.0402	0.0840	0.353	0.0185
	(0.0887)	(0.270)	(0.0841)	(0.0879)	(0.265)	(0.0814)
BV × Yr_{t-2}	-0.0147	-0.0304	-0.00707	-0.0229	-0.0450	-0.0165
	(0.0433)	(0.0653)	(0.0547)	(0.0432)	(0.0664)	(0.0541)
BV × Yr_{t-1}	ref.	ref.	ref.	ref.	ref.	ref.
BV × $Yr_{t=0}$	-0.113	0.0528	-0.153*	-0.103	0.0623	-0.140
	(0.0688)	(0.0674)	(0.0875)	(0.0690)	(0.0662)	(0.0879)
BV × Yr_{t+1}	-0.174**	-0.198	-0.171**	-0.156**	-0.173	-0.154**
	(0.0693)	(0.160)	(0.0784)	(0.0693)	(0.163)	(0.0768)
BV × Yr_{t+2}	-0.182**	-0.133	-0.187*	-0.152*	-0.0672	-0.159
	(0.0817)	(0.0865)	(0.103)	(0.0799)	(0.0699)	(0.100)
BV × Yr_{t+3}	-0.210**	-0.0562	-0.259**	-0.174**	0.0374	-0.234**
	(0.0899)	(0.101)	(0.116)	(0.0876)	(0.0737)	(0.112)
BV × Yr_{t+4}	-0.207*	-0.229*	-0.197	-0.154	-0.103	-0.154
	(0.106)	(0.133)	(0.132)	(0.0999)	(0.0844)	(0.123)
Mean of y (untreated)	0.574	0.112	0.714	0.574	0.112	0.714
Observations	2,968	602	2,366	2,968	602	2,366
R^2	0.008	0.047	0.008	0.018	0.178	0.014

Notes: Deforestation is the total area deforested in year t as a percentage of remaining forests in year $t-1$. Treatment is a dummy variable that equals one if an area eventually has BV-receiving households and zero otherwise. All specifications include Priority Area fixed effects and year fixed effects, as well as leads and lags of participation in the BV. The period prior to the BV enrollment is the omitted category. Covariate controls include clouds and interaction terms between lagged remaining forests and distances to the nearest paved roads and cities. Robust standard errors clustered at the Priority Area level in parentheses.

Table A5: Decomposition of Double Difference Estimate of the BV Program Impact

Dependent variable	Deforestation as a percentage of lagged remaining forests			
	Full sample			
	Inside cells		Outside Cells	
	(1)	(2)	(3)	(4)
Post × Receive	-0.0380*		0.112**	
	(0.0207)		(0.0499)	
SUC: Post × Receive		-0.0389*		0.130**
		(0.0204)		(0.0536)
SET: Post × Receive		-0.0355		0.0822*
		(0.0279)		(0.0456)
Mean of y	0.080	0.080	0.257	0.257
Observations	3,147,512	3,147,512	12.5 mil	12.5 mil
R^2	0.231	0.231	0.200	0.200

Notes: Dependent variable is the total area deforested in year t as a percentage of remaining forests in year $t-1$. Treatment is a dummy variable that equals one if the grid cell lies in a Priority Area that has BV-receiving households and zero otherwise. All specifications include cell fixed effects and year fixed effects. Covariate controls include clouds. Robust standard errors clustered at the Priority Area level in parentheses.

Table A6: DDD Estimated Impact of BV Intensity (Beneficiaries)

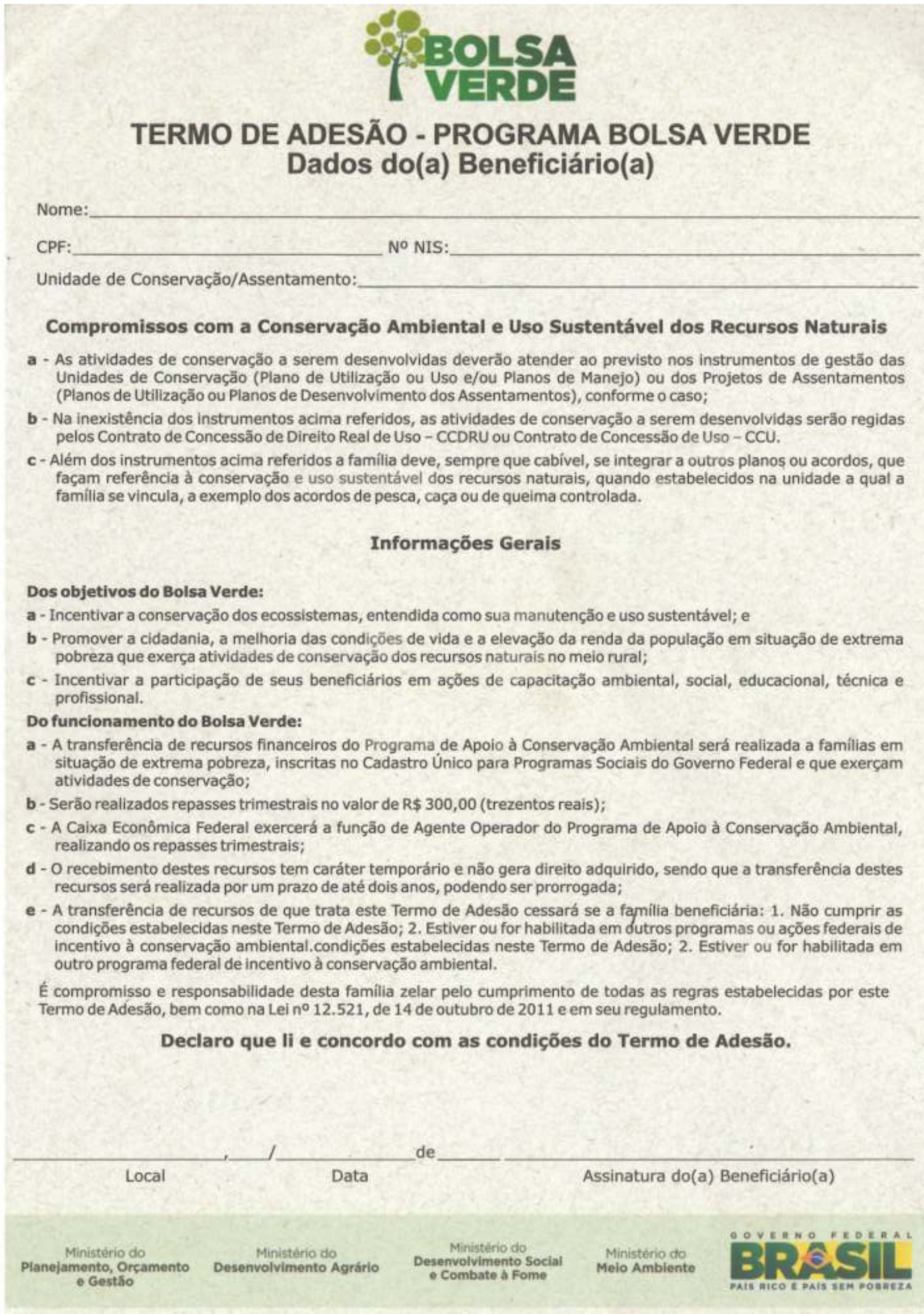
Dependent variable	Deforestation as a percentage of lagged remaining forests						
Type of area	All areas				Settlements		
Beneficiaries per km^2	< 0.5		0.5 to 1		1 to 5	5 to 10	> 10
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inside × Receive × Post	-0.179***		-0.187***				
	(0.0442)		(0.0437)				
SUC: Inside × Receive × Post		-0.196***		-0.199***			
		(0.0512)		(0.0510)			
SET: Inside × Receive × Post		-0.165**		-0.185***	-0.200**	-0.165	-0.108*
		(0.0655)		(0.0633)	(0.0800)	(0.103)	(0.0650)
Inside × Post	0.203***		0.203***				
	(0.0420)		(0.0420)				
Receive × Post	0.125***		0.124***				
	(0.0363)		(0.0362)				.
SUC: Inside × Post		0.193***		0.193***			
		(0.0483)		(0.0483)			
SUC: Receive × Post		0.149***		0.149***			
		(0.0398)		(0.0398)			
SET: Inside × Post		0.227***		0.227***	0.210***	0.210***	0.154***
		(0.0609)		(0.0609)	(0.0593)	(0.0593)	(0.0580)
SET: Receive × Post		0.0941**		0.0938**	0.0632*	0.0632*	0.0103
		(0.0372)		(0.0372)	(0.0325)	(0.0325)	(0.0274)
Constant	0.373***	0.373***	0.370***	0.369***	0.495***	0.496***	0.356***
	(0.0164)	(0.0163)	(0.0160)	(0.0159)	(0.0203)	(0.0204)	(0.0133)
Mean of y	.332	.332	.328	.328	.481	.483	.346
Observations	3,131,954	3,131,954	3,184,795	3,184,795	2,005,700	1,999,134	2,965,336
R^2	0.214	0.214	0.214	0.214	0.212	0.212	0.214

Notes: The dependent variable is deforestation in year t as a percentage of remaining forest in year $t-1$. All specifications include grid-cell and year fixed effects. Covariate controls include clouds. Robust standard errors clustered at the Priority Area level in parentheses.

Table A7: Triple Difference Estimates of Program Impact on Deforestation by Property Type

Dependent variable	Deforestation as a percentage share of lagged remaining forests				
Type of Property	Micro	Small	Medium	Large	Non CAR
	(1)	(2)	(3)	(4)	(5)
SUC: Inside × Receive × Post	-1.016	-0.955	-0.491***	-0.425***	-0.116***
	(0.926)	(0.620)	(0.157)	(0.0795)	(0.0424)
SET: Inside × Receive × Post	0.622	0.0379	-0.0793	-0.258***	-0.121**
	(1.163)	(0.566)	(0.327)	(0.0849)	(0.0502)
Inside SUC × Post	0.380	1.514**	0.356***	0.346***	0.114***
	(0.804)	(0.588)	(0.119)	(0.0596)	(0.0392)
Receive SUC × Post	0.171	0.143	0.252**	0.191***	0.112**
	(0.338)	(0.147)	(0.0995)	(0.0621)	(0.0457)
Inside SET × Post	-1.299	0.534	0.131	0.282***	0.146***
	(0.975)	(0.424)	(0.269)	(0.0764)	(0.0474)
Receive SET × Post	-0.0190	0.0378	0.213**	0.146**	0.0823**
	(0.314)	(0.243)	(0.107)	(0.0723)	(0.0409)
Constant	1.009***	0.909***	0.857***	0.529***	0.177***
	(0.262)	(0.262)	(0.146)	(0.0545)	(0.0259)
Mean of y	1.06	1.09	.634	.37	.122
Observations	325,187	254,493	100,489	56,594	14.7 mil
R^2	0.242	0.254	0.251	0.258	0.188

Notes: Dependent variable is deforestation at year t as a percentage share of remaining forests at year $t-1$ in each 1 km^2 grid cell. Each column reports triple difference estimates from separate specifications. Robust standard errors clustered at the Priority Area level are in parentheses.



BOLSA VERDE

TERMO DE ADESÃO - PROGRAMA BOLSA VERDE
Dados do(a) Beneficiário(a)

Nome:______________________________

CPF:________________ Nº NIS:________________

Unidade de Conservação/Assentamento:________________

Compromissos com a Conservação Ambiental e Uso Sustentável dos Recursos Naturais

a - As atividades de conservação a serem desenvolvidas deverão atender ao previsto nos instrumentos de gestão das Unidades de Conservação (Plano de Utilização ou Uso e/ou Planos de Manejo) ou dos Projetos de Assentamentos (Planos de Utilização ou Planos de Desenvolvimento dos Assentamentos), conforme o caso;

b - Na inexistência dos instrumentos acima referidos, as atividades de conservação a serem desenvolvidas serão regidas pelos Contrato de Concessão de Direito Real de Uso – CCDRU ou Contrato de Concessão de Uso – CCU.

c - Além dos instrumentos acima referidos a família deve, sempre que cabível, se integrar a outros planos ou acordos, que façam referência à conservação e uso sustentável dos recursos naturais, quando estabelecidos na unidade a qual a família se vincula, a exemplo dos acordos de pesca, caça ou de queima controlada.

Informações Gerais

Dos objetivos do Bolsa Verde:

a - Incentivar a conservação dos ecossistemas, entendida como sua manutenção e uso sustentável; e

b - Promover a cidadania, a melhoria das condições de vida e a elevação da renda da população em situação de extrema pobreza que exerça atividades de conservação dos recursos naturais no meio rural;

c - Incentivar a participação de seus beneficiários em ações de capacitação ambiental, social, educacional, técnica e profissional.

Do funcionamento do Bolsa Verde:

a - A transferência de recursos financeiros do Programa de Apoio à Conservação Ambiental será realizada a famílias em situação de extrema pobreza, inscritas no Cadastro Único para Programas Sociais do Governo Federal e que exerçam atividades de conservação;

b - Serão realizados repasses trimestrais no valor de R$ 300,00 (trezentos reais);

c - A Caixa Econômica Federal exercerá a função de Agente Operador do Programa de Apoio à Conservação Ambiental, realizando os repasses trimestrais;

d - O recebimento destes recursos tem caráter temporário e não gera direito adquirido, sendo que a transferência destes recursos será realizada por um prazo de até dois anos, podendo ser prorrogada;

e - A transferência de recursos de que trata este Termo de Adesão cessará se a família beneficiária: 1. Não cumprir as condições estabelecidas neste Termo de Adesão; 2. Estiver ou for habilitada em outros programas ou ações federais de incentivo à conservação ambiental.condições estabelecidas neste Termo de Adesão; 2. Estiver ou for habilitada em outro programa federal de incentivo à conservação ambiental.

É compromisso e responsabilidade desta família zelar pelo cumprimento de todas as regras estabelecidas por este Termo de Adesão, bem como na Lei nº 12.521, de 14 de outubro de 2011 e em seu regulamento.

Declaro que li e concordo com as condições do Termo de Adesão.

____________, ___/________ de ____ ________________

Local Data Assinatura do(a) Beneficiário(a)

Ministério do Planejamento, Orçamento e Gestão | Ministério do Desenvolvimento Agrário | Ministério do Desenvolvimento Social e Combate à Fome | Ministério do Meio Ambiente | GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

Figure A1: Terms of Adhesion Signed by Bolsa Verde Beneficiaries

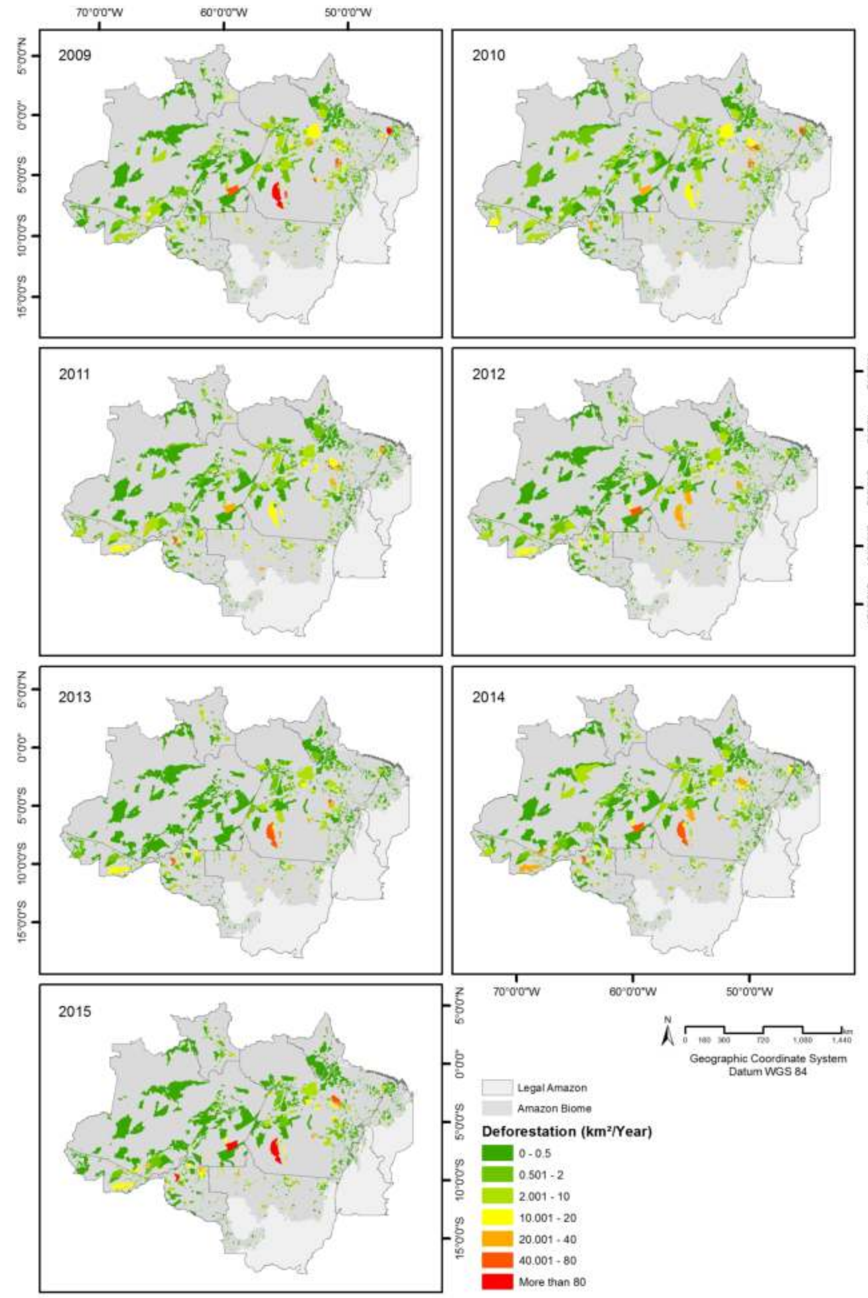


Figure A2: Annual Deforestation Rates in Areas Eligible for Bolsa Verde (2009 to 2015)

Notes: The figure plots annual area deforested in BV-eligible areas in our sample from 2009 to 2015. Deforestation levels are on average low, with a few exceptions (colored yellow, orange, and red). We observe both spatial and temporal changes in deforestation in the study region.

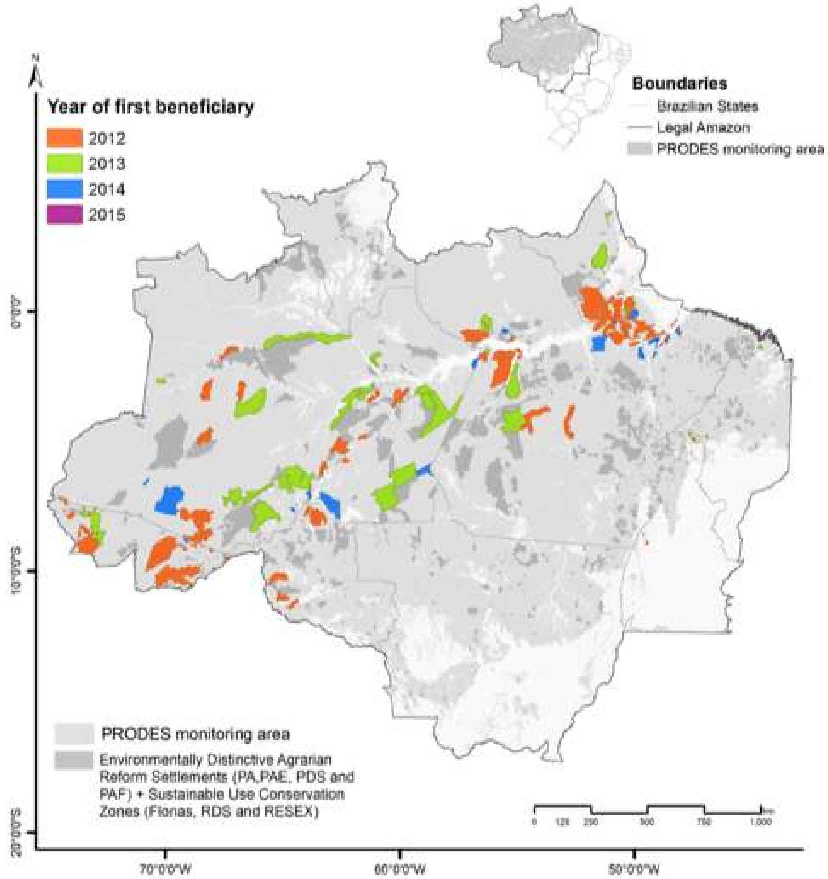


Figure A3: Bolsa Verde Priority Areas by Category

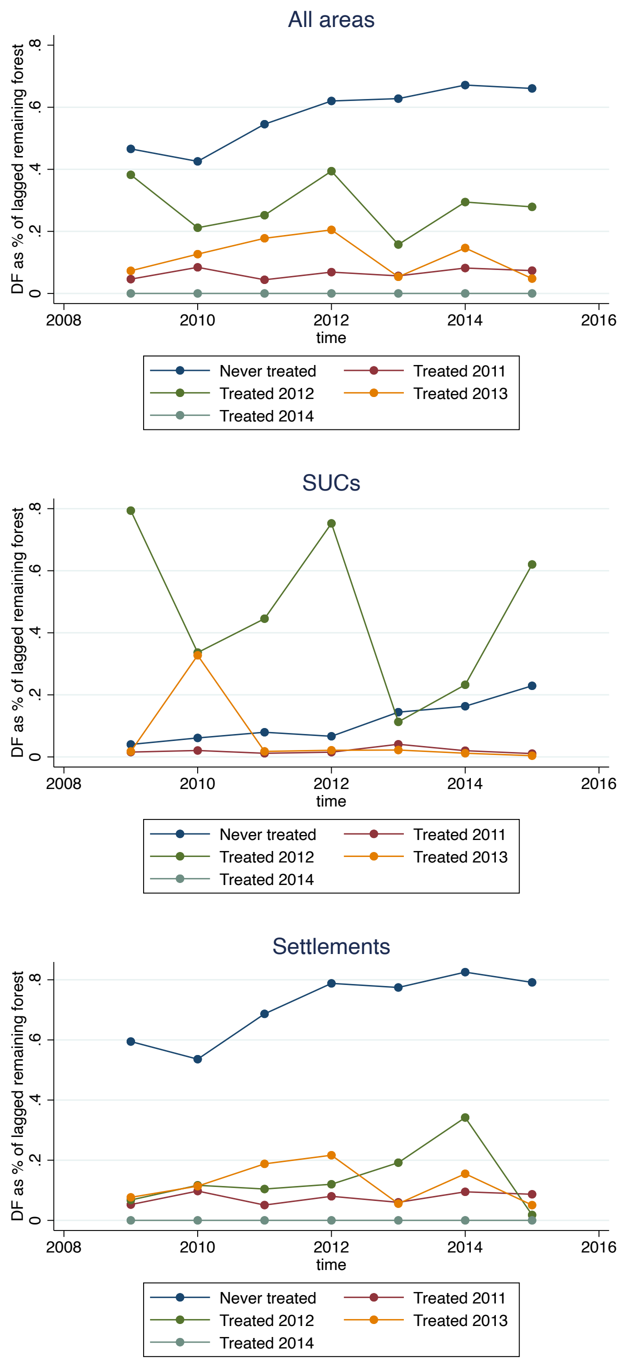


Figure A4: Mean Deforestation by BV Treatment Year

Notes: The figure plots the average percentage of lagged remaining forests deforested in BV-receiving and non-receiving Priority Areas.

Online Appendix

A REDD+ Project Classification by Incentive Structure

In this section we provide further evidence to illustrate the uniqueness of the Bolsa Verde program at a global level, using the International Database on REDD+ Projects linking Economic, Carbon and Communities data (ID-RECCO): www.reddprojectsdatabase.org

The database contains 110 variables for each REDD+ project, categorised into 8 main concepts: Location, Project Proponent(s), Contact Details, Project Information, Carbon Certification, Carbon Credits, Financing, and Communities Aspects. For direct comparability with the BV study, we consider only those projects in the database which use conditional cash payments as the incentive mechanism. These projects are then categorised by whether they use an individual-based incentive structure, a collective-based structure, or both - which has been completed manually using the online information sources recorded in the database for each project.

Projects are categorized as Collective, where both conditionality and payments are defined and administered at community level; as Individual, when conditionality and payments are individualized; and as Both, if they have applied both individual and collective-based incentive structures. None of the latter however has the same as BV incentive structure. For example, a large project covering a large land area would be classified as Both if they state that the payments/conditionality are based on the landowner, where landowners include both individuals and local community collectives. So in this case, both Individual and Collective based incentives have been used, separately, within the same project. Payments are made to individuals based on individual conditionality, and to collectives based on collective conditionality.

After removing projects that had been abandoned, those that do not have sufficient data to categorise their incentive scheme, and Jurisdictional projects (where the objectives and payments are made at the State level instead of the community level), we identified 123 projects as of September 2021. Among 123 projects: 60 used Individual-based incentives, 58 used Collective-based incentives and 5 projects included both inventive schemes. Only 54, however, have data available on total project costs. The breakdown of the final 54 projects can be seen in Table O1, which shows the total spending on REDD+ projects.

Table O1: REDD+ Project Classification by Incentive Structure

Incentive Structure	No. Projects	Total Financing ($)- Available Data
Individual	30	157,484,469
Collective	22	110,611,659
Both	2	2,199,999
Total	54	270,296,127

Source: International Database on REDD+ Projects linking Economic, Carbon and Communities data (ID-RECCO): www.reddprojectsdatabase.org

B Rural areas eligible for the BV program

Sustainable Use Conservation Zones: managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), these territories reconcile conservation with the sustainable use of natural resources. Public visitation is permitted, subject to the norms established for the management of the zone. Scientific research is possible.

The following subcategories are eligible for the BV:

- National Forests (FLONA): areas with forest cover of predominantly native species. The traditional populations that used to live within this area prior to its establishment are allowed to continue their residence.
- Extractive Reserves (RESEX): areas used by traditional extractive populations, whose subsistence is based on extractive activities, subsistence agriculture and small animal husbandry. Mineral resources and amateur or professional hunting are prohibited. Commercial exploitation of timber is allowed on a sustainable basis and in special situations.
- Sustainable Development Reserves (RDS): natural areas that shelter traditional populations, whose existence is based on sustainable natural resources exploitation, developed over generations and adapted to local ecological conditions.

Environmentally Distinctive Agrarian Reform Settlements: established by the National Institute of Colonization and Agrarian Reform (INCRA), these areas consist of independent agricultural units with a rural property that belonged to a single owner. INCRA delivers these units, called plots, lots or lands, to families with insufficient economic means to acquire and maintain a rural property. The size of the settlement depends on the land's ability to support settled families. The size and location of each lot is determined by the geography and productive conditions of the land.

Households with plots utilize them for their livelihoods, using family labor exclusively.

INCRA provides these families with credit, technical assistance, infrastructure, and other benefits to support their development. In addition to land distribution, settlements provide conditions for housing and family production and guarantee their food security.

The following subcategories are eligible for the BV:

- Settlement Projects (PA): implemented in areas intended for agrarian reforms, which are integrated to territorial and regional development. Actions include sustainable use of physical spaces and existing natural resources.[48]
- Agro Extractivist Settlement Project (PAE): designated for the use of areas endowed with extractive wealth through economically viable, socially fair and ecologically sustainable activities, to be executed by the extractive communities.[49]
- Forest Settlement Project (PAF): designated for areas with multiple use forest management as well as to provide for plantations with native species in cases where large proportions of land has already been converted to other productive activities.[50]
- Sustainable Development Project (PDS): created for the development of environmentally differentiated activities for communities whose subsistence do not depend on extractive activities. These communities often practice agriculture and other activities with low impact on the environment. In these areas, land titles are held collectively.[51]

[48]Normative Instruction No. 5, of Mar 30, 2004. `http://www.incra.gov.br/tree/info/file/2467`
[49]Portaria No. 268 of Oct 23, 1996. `http://www.incra.gov.br/tree/info/file/2397`
[50]Portaria No. 215, of Jun 6, 2006. `http://incra.gov.br/tree/info/file/2353`
[51]Portaria No. 477, of Nov 4, 1999. `http://www.incra.gov.br/tree/info/file/2395`

C Collective nature of the BV program, conditionality and household awareness

Within eligible areas, the federal organizations compile and submit lists of eligible households residing in enlisted areas to the Ministry of Social Development (MDS) for income validation. An eligible household formally becomes a beneficiary by making the commitment to engage in conservation and use natural resources in sustainable ways. This commitment is made in the form of a contract, which sets out details of the program, as well as the responsibilities of the families in terms of maintaining the zone's vegetation level and using natural resources in sustainable manners. The households were made aware of the collective nature of the goal and of its conditionality, when informed by the conservation unit manager or government bodies when they are were required to sign the Term of Adhesion to the program (Figure A1 in the Appendix).[52] The contract, however, does not stipulate that beneficiaries are to carry out monitoring activities as part of the responsibilities.

Households are informed by the conservation unit manager or government bodies when they are required to sign the Term of Adhesion to the program. The Term reinforces commitments to environmental conservation and sustainable use of natural resources.

"*a - The conservation activities to be developed must comply with the provisions of the management instruments of the Conservation Units (Use or Use Plan and Management Plans) or Settlement Projects (Use Plans or Settlement Development Plans), as appropriate.*"

"*c - In addition to the instruments as mentioned earlier, the family must, whenever appropriate, be integrated into other plans or agreements that refer to the conservation and sustainable use of natural resources, when established in the unit to which the family is linked, such as fishing,*

[52] Anecdotal evidence based on qualitative interviews with recipients suggests that those living in SUCs and Settlements are aware of where the areas' boundaries are.

hunting or controlled burning agreements."

Also, about the functioning of Bolsa Verde, the Term attests:

"e - The transfer of resources referred to in this Adhesion Term shall cease if the beneficiary family: 1. Does not comply with the conditions established in this Adhesion Term; 2. Is qualified in other federal programs or actions to encourage environmental conservation."

At the end of the Term, it is reinforced:

"It is the commitment and responsibility of this family to ensure compliance with all rules established by this Adhesion Term, as well as in Law No. 12,512, October 14, 2011 and its regulation."

The collective requirement for the area to be eligible for the program (vegetable cover compliance) is not mentioned in the Adhesion Term, and the Law No. 12,512 states that:

"Art 3 § 1 The Executive Power will define the procedures for verifying the existence of natural resources in the areas dealt with in items I to IV. (. . .)"

"Art. 8 The Executive Power will establish the Management Committee of the Environmental Conservation Support Program (Bolsa Verde), under the coordination of the Ministry of the Environment, with the following attributions, without prejudice to others defined in the regulation: (. . .) III - indicate priority areas for the implementation of the program, subject to the provisions of Art. 3."

According to the law, the vegetation cover compliance rule was decided internally by the program coordination and applied to prioritize the areas to be covered.

Source: `http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/lei/l12512.htm`

D How do BV recipients report?

At the local level, direct communication with families for implementing the BV is done by the local management bodies. These institutions refer beneficiaries, update their information and monitor compliance of the environmental conditions. We test the monitoring and reporting mechanism by comparing the effectiveness of the BV program in Sustainable Use Conservation Zones (SUCs) versus Settlements. SUCs have managers and community councils while Settlements often do not. Additionally, the program brought the managers of the SUCs closer to the program participants, due to the filling out of forms and other bureaucracies, and that the image of ICMBio employees (agency responsible for protected areas) changed from the old stereotype of inspector for more like a community agent. This increased the confidence of BV participants to report illegal activities within the units, by passing information to the manager or other employees. The BV beneficiaries also have a reporting channel on the internet and by phone, but the majority of reports are summitted through these informal channels.[53]

Additionally, migrants from the South were allocated plots of land to farm in Settlements during the 1970s, hence it is likely that residents in these areas make the majority of their living from agriculture and potentially use deforestation as a means for clearing land. As such, in the SUCs, monetary rewards are likely to be very strongly aligned with incentives to monitor and report on illegal deforesters, especially if their managers present a point of contact to report illegal deforestation, making the monitoring and reporting channel feasible. In contrast, in the Settlements, the underlying incentives are different as settlers were given land to farm. In addition, the incentives (or costs) of reporting the deforestation done by one's own neighbors are likely low (or high).

[53]This qualitative information has been gathered during a field trip of the authors of this project to Tefè National Forest. Also, see UFRRJ [2015] regarding the communications between the managers and the BV participants.

E Details of Bolsa Familia

Incompliance

In terms of the sanctions related to incompliance, the BF beneficiaries are subject to four stages with conditions that progressively become more severe: (1) notification, (2) blockage, (3) suspension, and (4) cancellation. Upon initial noncompliance with conditions, the family receives a notice, which remains in the family's compliance with conditions records during six months. If after those six months the family has a new episode of noncompliance, the family receives a new notice. On the other hand, if the family has another episode during the six months following receipt of the notice, the family is blocked. In this case, the payment of benefits is blocked for 30 days, but that payment can be picked up with the next month's payment. If during the six-month period following the blockage the family has another episode of noncompliance, the consequence will be suspension. The benefit can only be cancelled if the family is in the suspension phase (the six-month period following the last suspension [Hellmann, 2015].

F Forest and carbon data

Forest data

In the Brazilian Amazon, approximately 81 percent of the area is forested, 17 percent is cerrado (wooded grassland), and 1.8 percent is water [Skole and Tucker, 1993]. Using images from the Landsat LT-5, LT-7, and LT-8 satellites, PRODES calculates annual deforestation using the seasonal year, which starts from August in year t to July in year $t+1$.[54]

Carbon data

We resample the AGB map to the 1 km x 1 km grid cells, using the biomass average of all 30 meter pixels comprehended by the 1 km^2 pixel. The density was transformed to Mg per ha to Mg per km^2. We calculate the subsequent carbon loss using information on deforestation and remaining forests. Since the carbon map we use contain information on carbon in 2000 only, we overlay the carbon information with the remaining forest in 2000.[55] We then calculate carbon loss per year by multiplying carbon stock in 2000 with the ratio of remaining forests in each year to remaining forests in 2000.

Cells inside Priority Areas have more carbon than those outside, but conditional on being inside or outside, cells have similar distributions of carbon in eventually receiving or non-receiving Priority Areas. Figure O2 in the Appendix shows the distribution of car-

[54] Satellite images are selected as near to this date as possible for the calculation, generally from July, August, and September. PRODES only identifies forest clearings of 6.25 hectares or larger. Therefore, forest degradation or smaller clearings from fire or selective logging are not detected. For robustness, we will validate the analysis using Hansen et al. (2013)'s forest cover data.

[55] The biomass density (in Mg/ha) was generated by the statistical relationship between data collected in situ and LiDAR Geoscience Laser Altimeter System (GLAS), which contain data acquired over 40,000 points. In addition to the field data and GLAS, reflectance data derived from Landsat 7 ETM +, elevation data and biophysical variables were used in the estimation of carbon stock.

bon in 2010, prior to the BV program, among cells inside and outside Priority Areas that eventually participate in the BV (top panel) and those cells inside and outside Priority Areas that do not participate in the program (bottom panel). In terms of carbon dioxide value per hectare of area, evaluated at 50 USD per tonne of CO2, the majority of cells have carbon content worth around 25000.

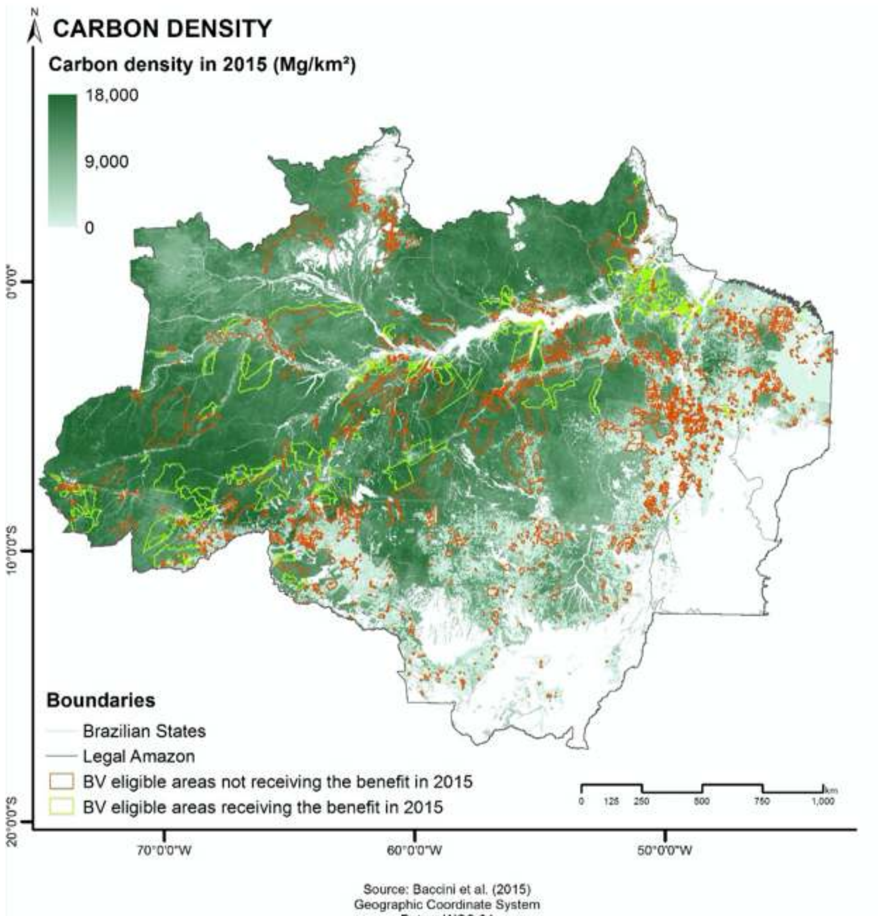


Figure O1: Carbon density in the Brazilian Legal Amazon.

Notes: Figure shows the calculated carbon stocks for each grid cell in 2015 based on carbon in 2000 and remaining forests in 2015.

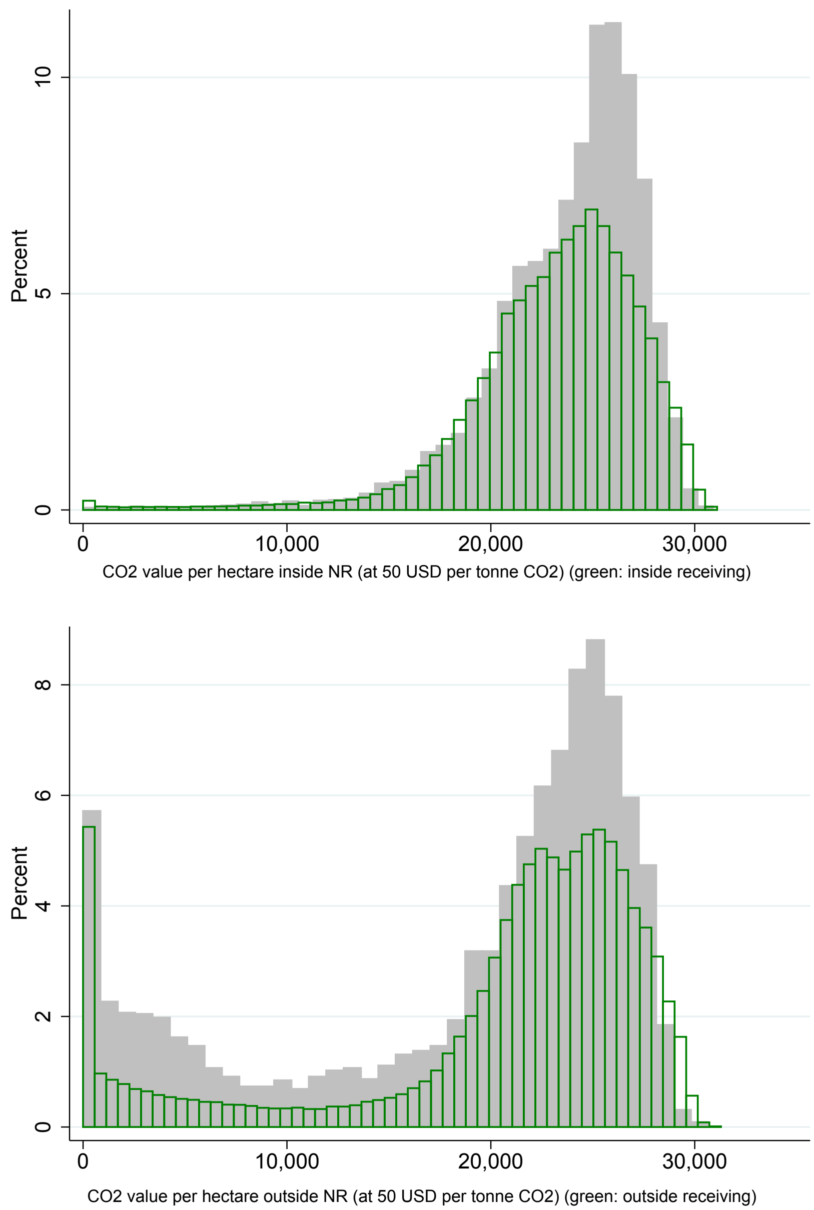


Figure O2: Distribution of Carbon

Notes: The figures show the distribution of carbon in cells. In the top panel, bars with green borders indicate the distribution of carbon in cells lying inside BV-receiving zones. Grey shaded bars show the equivalent in cells that are inside non-BV-receiving zones. In the bottom panel, bars with green borders show the amount and distribution of carbon in cells lying outside BV-receiving zones. Grey shaded bars show the equivalent in cells outside non-BV-receiving zones.

G Difference-in-Differences Robustness

To address the potential concern that receiving and non-receiving areas are systematically different prior to the program, and that some of these differences may explain their participation in the BV, we repeat the main analysis on a matched sample of similar receiving and non-receiving areas. Table **??** shows that results from the matched sample are consistent with the unmatched sample.[56]

We also test whether using the distance of each area from the nearest IBAMA office as a proxy for the strength of enforcement is a meaningful dimension of heterogeneity.[57] Table O2 shows that our main results are robust to controlling for these distances.

Table O2: Estimated Impact of BV on Deforestation by Distance to IBAMA

Dependent variable	Deforetation (%)					
	All		SUC		Settlements	
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.150**	-0.111	-0.213	-0.148	-0.147*	-0.143*
	(0.0699)	(0.0691)	(0.144)	(0.130)	(0.0842)	(0.0797)
Treatment X Distance to IBAMA	0.000182	0.0000048	0.000438	0.000337	0.000163	0.0000534
	(0.000147)	(0.000164)	(0.000438)	(0.000432)	(0.000169)	(0.000151)
Pre-BV deforestation in receving areas (%)	0.116		0.205		0.098	
Controls	No	Yes	No	Yes	No	Yes
Observations	2,961	2,961	602	602	2,359	2,359
R^2	0.004	0.017	0.015	0.144	0.005	0.024

Notes: Dependent variable is deforestation, the total area deforested in a given year as a percentage of 2008 remaining forests. Treatment is a dummy variable that equals one if an area has BV-receiving households and zero otherwise. All specifications include Priority Area fixed effects and year fixed effects. We calculate the average distance of all cells inside a Priority Area to the nearest IBAMA office. Covariate controls include clouds, lagged remaining forests, and interaction terms between lagged remaining forests and distances to the nearest paved roads and cities. Robust standard errors clustered at the Priority Area level in parentheses. R^2 of baseline specification in brackets.

[56] We carry out a coarsened exact matching procedure for non-receiving and receiving Priority Areas on a set of pre-program geophysical characteristics [Iacus et al., 2012]. Using 2009 to 2011 data, we match coarsely on the pre-BV average deforestation and remaining forests. We also divide the size of Priority Areas into ten bins and match Priority Areas across bins. Unmatched Priority Areas are dropped from the sample.

[57] Figure O3 shows the spatial distribution of IBAMA offices in the study area.

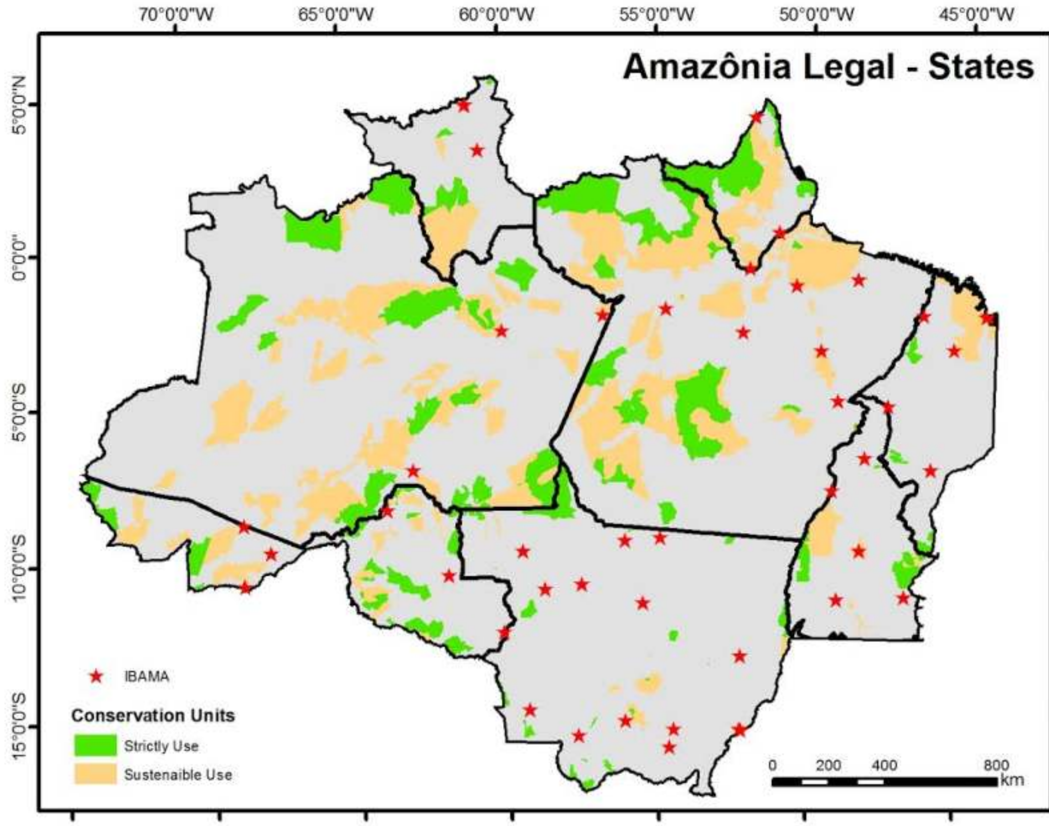


Figure O3: Location of IBAMA offices in the Legal Amazon

Notes: The figure plots the locations of IBAMA offices in the Legal Amazon.

Table O3: Difference-in-Differences Estimates of Program Impact on Deforestation by Recipients

Dependent variable	Deforestation as a % share of prior year remaining forests					
Treatment	Number of BV recipients per sqkm of the SUC or Settlement					
	All zones		SUC		SET	
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment effect	-0.0129**	-0.00735	-1.672	-1.461	-0.0142**	-0.00887
	(0.00523)	(0.00480)	(1.097)	(1.102)	(0.00622)	(0.00555)
Covariate controls	No	Yes	No	Yes	No	Yes
Mean of y	0.308	0.308	0.135	0.135	0.352	0.352
Observations	2,968	2,968	602	602	2,366	2,366
R^2	0.004	0.015	0.080	0.201	0.005	0.011

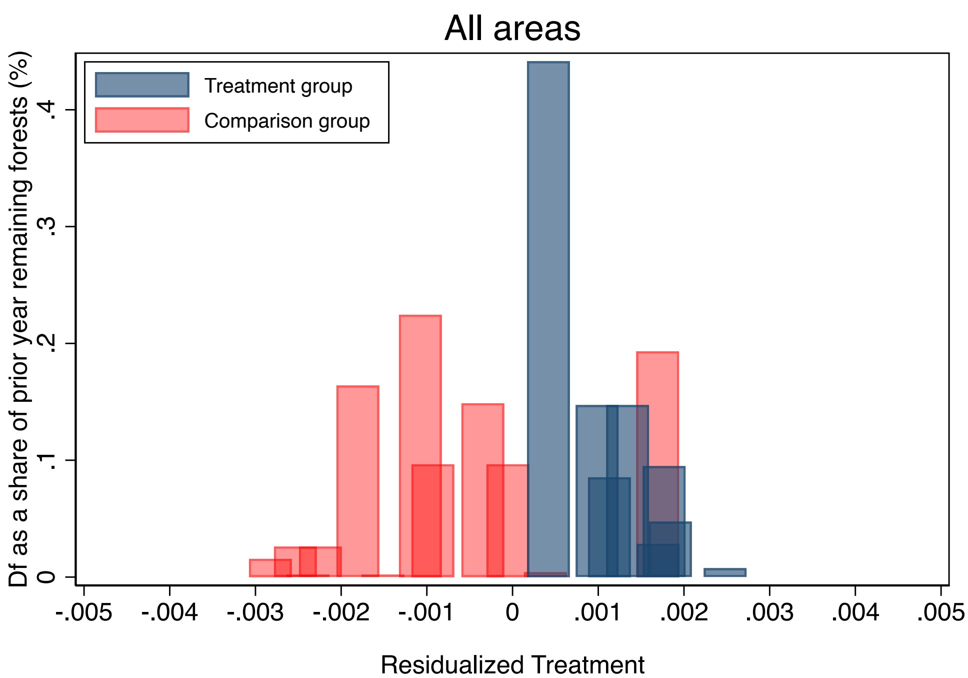
Notes: Dependent variable is deforestation at year t as a percentage share of remaining forests at year $t-1$ in each 1 km^2 grid cell. Each column reports triple difference estimates from separate specifications. Robust standard errors clustered at the Priority Area level are in parentheses.

Table O4: Difference-in-Differences Stacked Estimates

Dependent variable	Deforestation as a % share of lagged remaining forests			
	Baseline staggered TWFE		Pooled stacked	
	(1)	(2)	(3)	(4)
Treatment effect	-0.159**	-0.131**	-0.175***	-0.143***
	(0.0642)	(0.0625)	(0.0535)	(0.0534)
Controls	No	Yes	No	Yes
Mean of y	0.308	0.308	0.459	0.459
Observations	2,968	2,968	6,853	6,853
R^2	0.007	0.017	0.602	0.606

Notes: Dependent variable is deforestation at year t as a percentage share of remaining forests at year $t-1$ in each 1 km^2 grid cell. Each column reports triple difference estimates from separate specifications. Robust standard errors clustered at the Priority Area level are in parentheses.

Figure O4: Residualized Weights



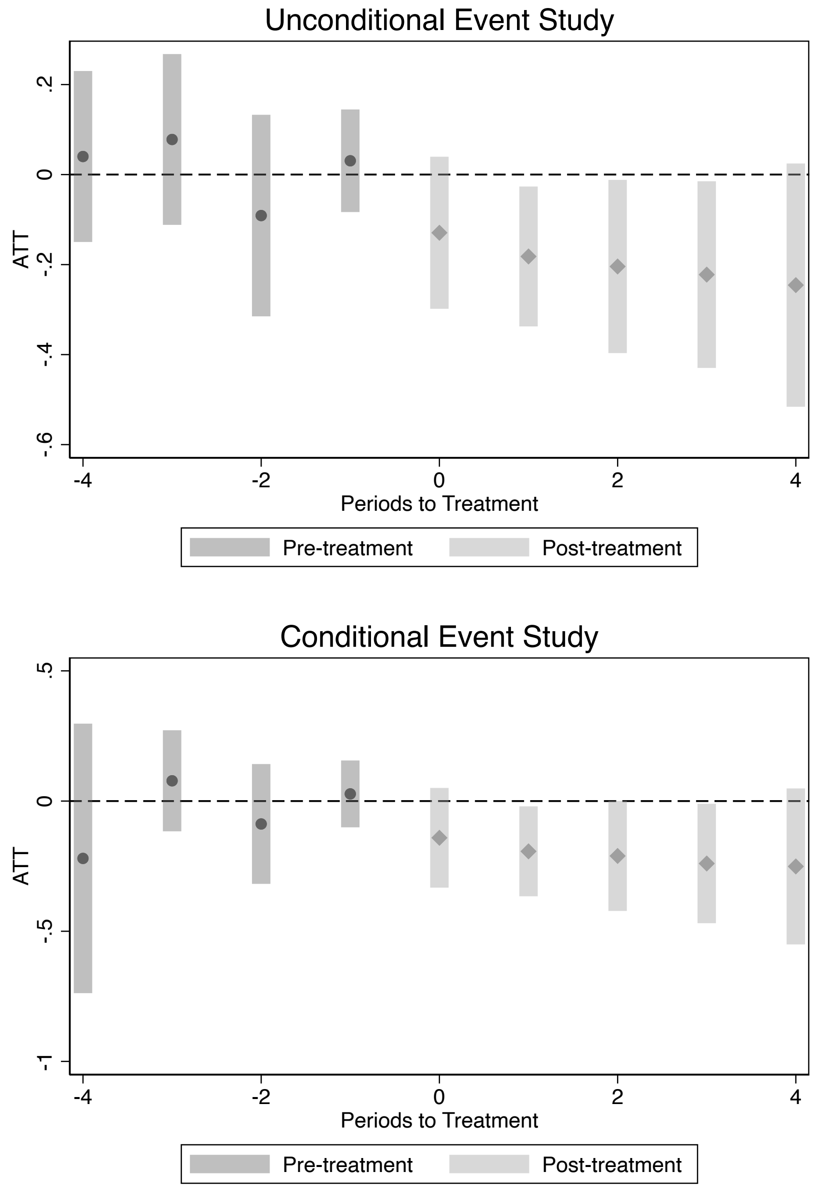


Figure O5: Two-Way Fixed Effects Estimator with Bias Correction: Estimated DD Impact of the BV on Deforestation

Notes: The figures show the event study estimates based on the [Callaway and Sant'Anna, 2021] estimator that corrects for potential bias of two-way fixed effects estimator when the implementation of the policy or event is staggered.

H Heterogeneity of Program Impact

Quadruple Difference Estimate by Income

Since the BV provides financial incentives for recipients to comply with the program and maintain forest cover in their areas of residence, we would expect the program to have a larger impact in poorer Priority Areas than in wealthier ones. Using data from the Brazilian Registry, we geocode households for which we have income information and place them into Priority Areas. We then calculate the average income across the sample of cells with which we have income information in each Priority Area. We assume that this average income level is representative for the entire Priority Area. Figure O6 shows the distribution of average income per head in our geocoded sample of households living in Settlements.[58] The mean income per head per month in both receiving and non-receiving Settlements in the geocoded sample is around 50 BRL.

Based on this average income level, we check whether the DDD estimates presented in Table 2 are mainly driven by cells in poor areas. Table O6 reports the estimates. The DDD estimate of the impact of the BV on deforestation is more negative when interacted with a *Poor* dummy (column 1), indicating Priority Areas with less than $ 77 Reais per month per household head, the extreme poverty threshold below which the BV grant is given. Conditional on a Priority Area being poor by this definition , the DDD estimate is more positive the higher the average income among households in the Priority Area (column 2). There is no differential effect of the BV, however, when we limit the sample to cells in non-poor areas (column 3). These results suggest that the program impact on reducing deforestation is larger where the financial payments represent a larger addition to the household budget for beneficiaries.

[58]We have a limited number of households with information on income and/or a full address suitable for geocoding in SUCs.

Table O5: Descriptive Statistics of Geocoded Sample in Settlements

	Receiving				Non-Receiving			
	2012	2013	2014	20015	2012	2013	2014	20015
Average income per head	37.960	40.193	47.037	61.334	45.714	54.065	66.085	85.386
	(13.246)	(13.938)	(15.970)	(18.412)	(24.663)	(31.817)	(33.477)	(43.711)
Number of geocoded households in Social Registry	174.782	186.553	190.371	190.721	48.265	49.559	49.559	47.412
	(308.132)	(325.488)	(341.190)	(340.519)	(48.042)	(48.421)	(48.545)	(46.519)
25 percentile of income per head	19.759	18.467	18.322	19.249	19.926	17.382	21.426	31.162
	(13.128)	(12.405)	(11.886)	(12.226)	(18.574)	(13.345)	(16.253)	(41.69)
Share of households receiving Bolsa Verde	0.660	0.647	0.641	0.643	-	-	-	-
	(0.217)	(0.215)	(0.214)	(0.215)	-	-	-	-
Share of households under Bolsa Verde thresehold	0.779	0.863	0.869	0.818	0.777	0.807	0.757	0.666
	(0.163)	(0.120)	(0.087)	(0.095)	(0.206)	(0.171)	(0.170)	(0.212)
% of remaining forests deforested	1.110	0.069	0.129	0.070	2.160	1.840	1.781	1.248
	(7.527)	(0.332)	(0.611)	(0.434)	(6.375)	(2.863)	(2.470)	(2.352)
Observations (number of priority areas)		197				34		

Notes: The table reports averages per year per type of Priority Area. Standard deviations are in parentheses.

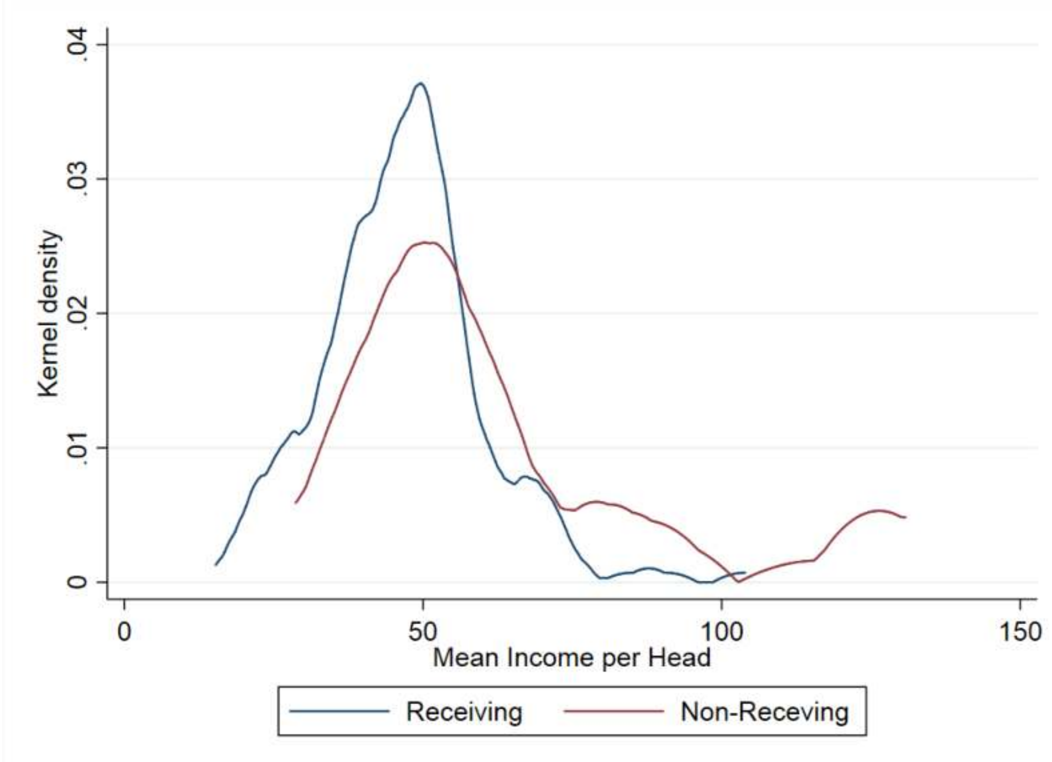


Figure O6: Distribution of Income per Head in Settlements

Notes: The figure plots the distribution of average income per head among receiving and non-receiving Settlements. We use information on income from the subgroup of households that we are able to geocode and place into BV eligible areas from the Social Registry. The assumption is that the geocoded subsample is random with respect to income and the distribution of mean income per head shown is representative of the true distribution and errors are not systematically different by BV receiving status. The mean income per head is an average over 2012 to 2015. The distribution of non-receiving Settlements is slightly to the right of the distribution of receiving households, suggesting that the former group of Settlements are wealthier, on average.

Table O6: Triple-Difference Estimates of Program Impact by Income

Dependent variable	Deforestation as percentage of lagged remaining forests		
Sample	All	Poor	Non-poor
	(1)	(2)	(3)
Inside × Receive× Post	0.774	-147.3***	4.693
	(0.591)	(26.58)	(4.440)
Inside × Receive× Post× Poor	-7.332**		
	(3.695)		
Inside × Receive× Post× Income		2.670***	-0.0332
		(0.518)	(0.0344)
Inside × Post× Poor	6.296*		
	(3.525)		
Receive× Post× Income		-0.0151**	0.000400
		(0.00714)	(0.00197)
Inside × Post× Income		-2.673***	0.00358
		(0.516)	(0.00277)
Post× Income		0.00978*	-0.00114
		(0.00572)	(0.00166)
Inside × Post	0.254	147.5***	-0.322
	(0.274)	(26.48)	(0.310)
Receive× Post	-0.306	0.796**	-0.389
	(0.491)	(0.403)	(0.520)
Constant	0.198**	0.237***	0.0392
	(0.0829)	(0.0912)	(0.192)
Mean of y	.100	.108	.080
Observations	15,872	11,694	4,178
R^2	0.2	0.2	0.2

Notes: Dependent variable is total area deforested in each 1 km^2 grid cell in year t as a percentage share of remaining forests in year $t-1$. *Poor* is a dummy variable that equals one if the average income among households in the Priority Area is below $ 77 Reais per month per head, the BV income threshold. *Income* denotes the average monthly per head income in the Priority Area. Each column reports triple-difference estimates from separate specifications. All specifications include cell and year fixed effects. Controls include clouds. Robust standard errors clustered at the Priority Area level are in parentheses.

I Matching

We conduct the matching in two groups. First, we match cells inside ever-receiving BV areas with cells inside ever-non-receiving but eligible areas. Second, we match cells outside ever-receiving BV areas with cells outside ever-non-receiving eligible areas. The assumption here is that cells inside eligible areas (either a conservation zone or a settlement) are more similar with each other in terms of the underlying tendency for deforestation prior to the BV program. Similarly for outside cells. Matching characteristics determine deforestation levels prior to the program.

We conduct the matching in three approaches: a "relaxed" approach, where we use only each cell's distance to the border of the nearest area and remaining forest as covariates; a "strict" approach, in which we use additional covariates as matching characteristics, including latitude, longitude, distance to rivers, cities, and roads; and finally a "both" way, in which we consider a cell to be matched with another one if and only if they are also matched in both the "relax" and "strict" methods. Tables O7 and O8 presents the summary statistics of the matching characteristics as well as the sum of the normalized differences across all the matched covariates (columns 6 to 9). Considering the reduction in normalized differences across both the inside and outside samples, the "strict" method is the best out of the three. The rule of thumb is that the normalized difference should not be more than 0.25 standard deviations). Therefore, our preferred matching sample for the remainder of the analysis is derived from the strict method.

Table O7: Summary Statistics of Inside Cells: Receiving, Non-Receiving and Matched Samples

Sample: inside cells	Receiving	Non-receiving	Matched non-receiving			Normalized difference (1) versus (2)	Normalized difference (1) vs (3)	Normalized difference (1) vs (4)	Normalized difference (1) vs (5)
			Relax	Strict	Both				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Deforestation (%)	0.0185	0.0553	0.000695	0.000574	0.000837	-0.03	-0.04	-0.03	-0.05
	(0.430)	(1.088)	(0.0123)	(0.0127)	(0.0128)				
Remaining forest (km)	0.960	0.970	0.967	0.964	0.947	-0.04	-0.03	-0.02	0.06
	(0.163)	(0.141)	(0.149)	(0.144)	(0.170)				
Distance to zone border (km)	7.472	9.200	7.628	6.252	5.537	-0.15	-0.02	0.14	0.23
	(6.693)	(9.355)	(6.596)	(5.889)	(5.133)				
Latitude	-5.444	-4.653	-4.536	-5.671	-5.559	-0.18	-0.21	0.05	0.03
	(3.118)	(3.057)	(3.091)	(2.852)	(2.896)				
Longitude	-61.51	-61.23	-60.64	-62.19	-61.96	-0.03	-0.10	0.08	0.05
	(6.593)	(5.519)	(5.473)	(5.592)	(5.616)				
Distance to the nearest rivers (km)	22.597	21.225	21.234	20.436	19.155	0.05	0.05	0.08	0.12
	(22.629)	(17.739)	(18.032)	(16.891)	(16.643)				
Distance to the neareset roads (km)	55.566	61.002	55.122	55.511	54.165	-0.08	0.01	0.00	0.02
	(41.124)	(58.328)	(55.762)	(46.262)	(46.470)				
Distance to the nearest cities (km)	73.468	93.992	93.682	77.305	75.046	-0.34	-0.33	-0.08	-0.03
	(35.422)	(49.379)	(51.101)	(33.297)	(34.012)				
Observations/ Sum Nd.	204,413	449,775	308,454	217,657	218,462	0.90	0.79	0.48	0.59

Notes: We follow the procedure described in Alix-Garcia et al. [2015] to pre-match receiving and non-receiving cells. Matches are found using 1:1 covariate matching with replacement on the Mahalanobis metric on the 2011 cross-section. Exact matches are required within administrative category (i.e. SUC or Settlement). Other matched covariates are pre-BV (2011) deforestation, remaining forest, latitude, longitude, as well as distances to the zone borer, nearest river, nearest road, and nearest city. Normalized difference is the difference in average covariate values, divided by the square root of the sum of variances for both groups (Imbens and Wooldridge [2009]). The last row in columns (6) to (9) gives the sum of the normalized differences across all the matched covariates.

Table O8: Summary Statistics of Outside Cells: Receiving, Non-Receiving and Matched Samples

Sample: Outsize cells	Receiving	Non-receiving	Matched non-receiving			Normalized difference (1) versus (2)	Normalized difference (1) vs (3)	Normalized difference (1) vs (4)	Normalized difference (1) vs (5)
			Relax	Strict	Both				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Deforestation (%)	0.0327	0.111	0.000775	0.000809	0.000738	-0.05	-0.03	-0.04	-0.03
	(0.685)	(1.593)	(0.0133)	(0.00976)	(0.0118)				
Remaining forest (km)	0.810	0.448	0.778	0.700	0.875	0.60	0.06	0.19	-0.14
	(0.372)	(0.469)	(0.394)	(0.428)	(0.306)				
Distance to zone border (km)	-29.40	-31.06	-30.12	-35.35	-35.35	0.05	0.02	0.15	0.15
	(26.14)	(25.84)	(26.34)	(29.71)	(29.53)				
Latitude	-4.632	-7.723	-6.200	-4.815	-4.693	0.54	0.31	0.04	0.02
	(2.829)	(4.915)	(4.213)	(2.927)	(2.735)				
Longitude	-62.15	-56.51	-59.82	-60.57	-63.32	-0.61	-0.25	-0.16	0.14
	(6.400)	(6.686)	(6.506)	(7.093)	(5.484)				
Distance to the nearest rivers (km)	17.565	18.612	18.370	13.959	15.267	-0.04	-0.03	0.15	0.10
	(19.351)	(16.576)	(16.218)	(13.850)	(13.597)				
Distance to the neareset roads (km)	56.640	17.972	36.449	43.201	60.810	0.64	0.30	0.20	-0.06
	(50.025)	(33.789)	(44.322)	(43.569)	(45.200)				
Distance to the nearest cities (km)	63.723	48.269	65.386	55.757	66.851	0.29	-0.03	0.15	-0.06
	(37.840)	(36.282)	(40.970)	(37.029)	(34.252)				
Observations/ Sum Nd.	331,874	1,816,437	575,292	336,369	333,751	2.82	1.03	1.08	.0.70

Notes: We follow the procedure described in Alix-Garcia et al. [2015] to pre-match cells just outside receiving and non-receiving areas. Matches are found using 1:1 covariate matching with replacement on the Mahalanobis metric on the 2011 cross-section. Exact matches are required within administrative category (i.e. SUC or Settlement). Other matched covariates are pre-BV (2011) deforestation, remaining forest, latitude, longitude, as well as distances to the zone borer, nearest river, nearest road, and nearest city. Normalized difference is the difference in average covariate values, divided by the square root of the sum of variances for both groups (Imbens and Wooldridge [2009]). The last row in columns (6) to (9) gives the sum of the normalized differences across all the matched covariates.

Table O9: Triple Difference Estimates of Program Impact on Deforestation at Cell Level: Matched Sample

Dependent variable	Deforestation as a percentage of lagged remaining forests			
	All cells		5 km inside or outside	
	(1)	(2)	(3)	(4)
Inside × Receive × Post	-0.0244		-0.193*	
	(0.0435)		(0.113)	
SUC: Inside × Receive × Post		-0.0459		-0.238*
		(0.0458)		(0.122)
SET: Inside × Receive × Post		0.0429		-0.0986
		(0.0927)		(0.136)
Inside × Post	0.0385		0.208*	
	(0.0427)		(0.112)	
Receive × Post	-0.000691		0.165	
	(0.0358)		(0.113)	
SUC: Inside × Post		0.0488		0.231*
		(0.0449)		(0.121)
SUC: Receive × Post		0.00928		0.186
		(0.0365)		(0.114)
SET: Inside × Post		-0.00922		0.141
		(0.0905)		(0.135)
SET: Receive × Post		-0.0171		0.138
		(0.0363)		(0.113)
Mean of y	.0546	.0546	.0787	.0787
Observations	3,649,755	3,649,755	1,070,809	1,070,809
R^2	0.213	0.213	0.214	0.214

Notes: Dependent variable is deforestation at year t as a percentage share of remaining forests at year $t-1$ in each 1 km^2 grid cell. Each column reports triple difference estimates from separate specifications. All models include cell fixed effects and year fixed effects. Robust standard errors clustered at the Priority Area level are in parentheses.

J Fines

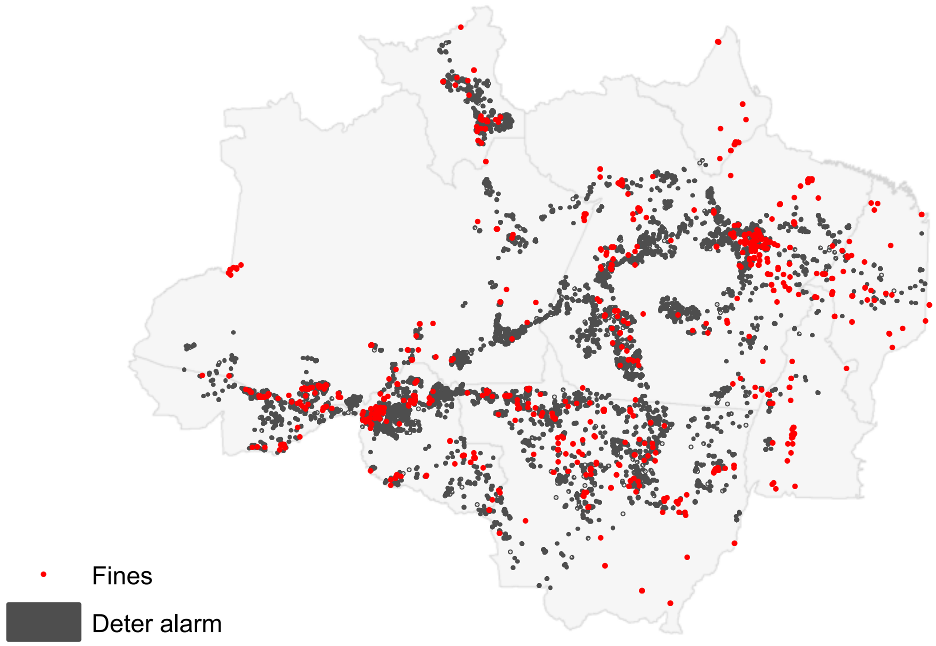


Figure O7: Distribution of fines and DETER Alarms in 2015

Notes and Source: The map plots the location of fines issued by either IBAMA or ICMBio, as well as DETER alarms (data from INPE) in the Legal Amazon in 2015. When fines and DETER alarm locations overlap, it is suggestive that the fines are due to the alarm. However, in regions where a fine was issued but no alarm was set off, then we have reasons to believe that the fine was issued due to intelligence from other sources, such as the reports by locals.

Table O10: DDD Estimated Impact of the BV Program on Fines

Dependent variable	Log of overlapping fines (≤5 km from nearest alarm)					
Type of fines	All	Deforestation	Other	All	Deforestation	Other
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × Receive × Post	0.00576	0.00727	-0.00170			
	(0.00657)	(0.00638)	(0.00156)			
SUC: Inside × Receive × Post				-0.00912	-0.00359	-0.00659
				(0.0140)	(0.0119)	(0.00657)
SET: Inside × Receive × Post				0.0145*	0.0149*	-0.000382
				(0.00838)	(0.00838)	(0.000910)
Constant	0.0107***	0.0102***	0.000589**	0.0107***	0.0103***	0.000550*
	(0.00248)	(0.00244)	(0.000267)	(0.00241)	(0.00237)	(0.000285)
Mean of y	.0164	.0157	.000845	.0164	.0157	.000845
Observations	87,694	87,694	87,694	87,694	87,694	87,694
R^2	0.371	0.368	0.375	0.371	0.368	0.376

Notes: The dependent variable is the log of the number of overlapping fines (defined as fines that lie within 5km from the nearest alarm). The treatment is a dummy variable that equals one if the cell lies in a Priority area that has BV-receiving households, and zero otherwise. All specifications include grid-cell fixed effects and year fixed effects. Covariate controls include cloud cover and deforestation. Robust standard errors clustered at the Priority Area level in parentheses.

Table O11: DDD Estimated Impact of the BV Program on Fines

Dependent variable	Log of Non-overlapping fines (>1 km from nearest alarm)					
Type of fines	All	Deforestation	Other	All	Deforestation	Other
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Receive × Post	0.0167	0.0159	0.00210			
	(0.0107)	(0.00975)	(0.00326)			
SUC: Inside × Receive × Post				0.0277*	0.0265***	0.00258
				(0.0142)	(0.0101)	(0.00824)
SET: Inside × Receive × Post				0.00718	0.00940	-0.00162
				(0.0180)	(0.0172)	(0.00209)
Constant	0.00303	0.00334	-0.000173	0.00270	0.00318	-0.000382
	(0.00563)	(0.00584)	(0.000674)	(0.00551)	(0.00573)	(0.000674)
Mean of y	.00956	.00909	.000577	.00956	.00909	.000577
Observations	86,865	86,865	86,865	86,865	86,865	86,865
R^2	0.357	0.355	0.359	0.357	0.355	0.359

Notes: The dependent variable is the log of the number of non-overlapping fines (defined as fines that lie more than 1km from the nearest alarm). The treatment is a dummy variable that equals one if a cell lies inside a Priority Area that has BV-receiving households, and zero otherwise. All specifications include grid-cell fixed effects and year fixed effects. Covariate controls include cloud cover and deforestation. Robust standard errors clustered at the Priority Area level in parentheses.

Table O12: DDD Estimated Impact of the BV Program on Fines

Dependent variable	Log of Overlapping fines (≤1 km from nearest alarm)					
Type of fines	All	Deforestation	Other	All	Deforestation	Other
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × Receive × Post	0.000942	0.000875	-0.0000618			
	(0.00434)	(0.00420)	(0.000368)			
SUC: Inside × Receive × Post				-0.0109	-0.0106	-0.000704
				(0.00919)	(0.00880)	(0.000748)
SET: Inside× Receive × Post				0.00578*	0.00558*	0.000123
				(0.00314)	(0.00298)	(0.000383)
Constant	0.00533**	0.00503**	0.000443**	0.00527**	0.00497**	0.000437**
	(0.00230)	(0.00228)	(0.000186)	(0.00225)	(0.00222)	(0.000185)
Mean of y	.0111	.0107	.000562	.0111	.0107	.000562
Observations	87,120	87,120	87,120	87,120	87,120	87,120
R^2	0.384	0.381	0.401	0.384	0.382	0.401

Notes: The dependent variable is the log of the number of overlapping fines (defined as fines that lie within 1km from the nearest alarm). The treatment is a dummy variable that equals one if a cell lies inside a Priority Area that has BV-receiving households, and zero otherwise. All specifications include grid-cell fixed effects and year fixed effects. Covariate controls include cloud cover and deforestation. Robust standard errors clustered at the Priority Area level in parentheses.

K Cost Effectiveness of the BV Program

We conduct a back-of-the-envelope calculation to evaluate the treatment effect on forest loss in terms of averted CO_2 emissions. In Table 1, we estimate that the reduction in deforestation is 0.05 to 0.1 percentage points (columns 3 and 4) or about 175 to 350 ha (average 262 ha) more in BV-receiving SUCs than non-receiving areas.[59] We use the matched carbon and deforestation data described in section 3. In 2015, areas eligible for the BV contained 105.8 $\pm$ 30.6 Mg of carbon per ha (1 Mg is 1 metric ton). Among the eligible areas, SUCs had higher carbon stock (127.3 $\pm$ 0.7 Mg per ha) than Settlements (92.6 $\pm$ 36.3 Mg per ha).

We translate our results into (262 ha x 127 MT) = 33,274 MT of carbon sequestered per SUC. Assuming that all the carbon in the cleared forest is turned into omitted CO_2, we multiply the carbon figures by 44/12, arriving at (34,274 MT x 3.67) = 122,116 MT of averted CO_2 emissions. We also value the CO_2 at 50 USD per tonne (in 2020 prices), which is a reasonable estimate of the social cost of carbon in 2020 (see for example Howard and Sylvan [2015]). Program benefits in SUCs are approximately USD 6 million per area or USD 263 million for all the 43 SUCs in our sample.[60] A similar calculation for Settlements yields (46 ha x 93 MT) = 4,278 MT of carbon sequestered per area, or 15,700 MT of averted CO_2 emissions. Valuing the CO_2 at 50 USD per tonne (in 2020 prices), benefits on Settlements are approximately USD 0.79 million per area or USD 153 million in total.[61]

[59]The stock of remaining forests prior to the BV program in SUCs in 2008 is about 350,000 ha.

[60]If we follow [Jayachandran et al., 2017] to use the SCC value of USD39 for 2012 in 2012 U.S. dollars, the benefits are 122,116 X 39 X 43 = 204 million. Alternatively, if we adopt the the recent SCC estimations at the country-level by Ricke et al. [2018], and use Brazil's SCC of USD24, then the total benefits of the SUCs would be 126 million

[61]There are 195 receiving Settlements in our analysis sample.