Does it Work to Pay to be Green? Evidence from Brazil's Bolsa Verde Program

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January, 2018

PRELIMINARY: PLEASE DO NOT CITE

Abstract

Whether and how policies can induce conservation at the optimal levels remain an open question. We evaluate the impact of Brazil's Bolsa Verde (BV) - a cash transfer program conditional on forest conservation - as a case study. The program provides both financial and social incentives for conservation and we test the relative strengths of both. We link spatial data on deforestation and remaining forest with the socioeconomic characteristics of eligible areas. We find less deforestation in eligible areas with beneficiaries. We also show that the number of recipients in a priority area is important for how effective the program is in reducing deforestation. In terms of mechanisms, financial incentives do not drive the success of BV, which is equally effective in relatively poorer and nonpoor areas. Instead, our results suggest that the BV contract, which makes all recipients liable for the forest cover in their areas of residence as a group, contribute to the success of BV by encouraging group conservation and monitoring.

***JEL**: I38, L14,O13, O15, Q23, Q28, Q56, Q57*

***Keywords**: deforestation, conditional cash transfer, contracts, conservation, Amazon*

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†The project is funded by the Research Council of Norway (project number 230860). We would like to thank Ana Carolina Pessoa for her excellent research assistance with maps and spatial data. We also thank Kelsey Jack, Katharine Sims and participants at various conferences for very helpful comments and discussions. Remaining errors are our own.

1 Introduction

Whether and how policies can induce conservation at the optimal levels remain an open question. The social transfers literature has become increasingly skeptical about the role of conditionality in determining the success of these programs. Empirical evidence on effective programs with unconditional transfers abound, including Duflo (2003)'s study on the old-age pension scheme in South Africa, as well as several studies using data from the GiveDirectly program (see e.g. Baird et al. 2011, 2012; Haushofer and Shapiro 2016). In the Payments for Ecosystem Services (PES) literature, however, there is a lack of consensus about the mechanisms that determine the effectiveness of these programs (see e.g. Alic-Garcia, Sims, and Yanez-Pagans 2015; Simonet et al. 2015) [1].

In this paper, we evaluate the impact of Brazil's Bolsa Verde (BV) program on deforestation and household outcomes as well as explicitly test the role of possible mechanisms. We link spatial data on deforestation and remaining forest with the socio-economic characteristics of eligible areas. Our work differs from Alix-Garcia et al. (2013) in that BV is a cash transfer program with an environmental conditionality on forest conservation, as opposed to being a PES program. The unique set up of BV allows the identification of the effect of committing to the program's conditionality through a contract separately from the effect of an increase in income through the cash transfer. While the contractual effect on deforestation is expected to be negative, the cash effect is ambiguous. If the increase in household income as a result of the cash transfer raises demand for land-intensive agricultural products, deforestation may increase as more forest land is cleared for agricultural production. In contrast, if the increase in household income raises demand for forest resources, deforestation may decrease (see e.g. Dasgupta et al. 2002; Foster and Rosenzweig 2003).

To identify the total effect of BV on deforestation, we first compare the deforestation rates of eligible areas with and without BV beneficiaries using a generalized difference-in-differences framework. We find that BV is associated with 0.94 km^2 per year less deforestation, a reduction of 76% compared to the pre-BV average (significant at the 5% level). Moreover, we find that this negative effect of BV on deforestation differs by program intensity: an additional BV recipient is associated with 0.0028 km^2 less forest loss per year. Given the total number of 7,798 BV recipients in conservation zones in our analysis sample, this result implies that scaling up BV in these areas by doubling its demographic coverage translates

[1] In her study of deforestation in Uganda, Jayachandran (2013) suggests that PES program offer a steady flow of payments in exchange for a flow of pro environmental behavior. As such, PES programs may face low take up when opportunity costs of participatns are more front loaded than the time profiles implied by a typical PES program.

into an additional 21.8 km^2 less deforestation per year. These results suggest that BV is able to achieve its goal of reducing deforestation in places where the program is implemented.

After presenting our estimation of the total effects of BV on deforestation, we explore the mechanisms through which BV has a distinct effect on deforestation. We hypothesize that the cash payment of BV provides financial incentives for compliance with the contract to maintain forest cover in the priority area of residence. If this was the case, we would expect that BV has a higher impact on deforestation in poorer priority areas than in wealthier ones. Priority areas are divided into three poverty groups: nonpoor, poor, and extremely poor. We show that financial incentives do not drive the success of BV, which is equally effective in relatively poorer and nonpoor areas. We also hypothesize that the BV contract provides social incentives for compliance with BV. Since BV recipients risk losing payments as a group if the forest cover in the priority area no longer complies with the Forest Code (80% of forests), there might be social incentives for recipients to collectively maintain the forest cover. Our preliminary results suggest that households may engage in group monitoring, which in turn contributes to the success of BV in reducing deforestation.

This paper adds to the literature by taking advantage of the unique features of Bolsa Verde to explore the financial and social mechanisms that drive its total impact on deforestation. By doing so, our study advances the literature on the enviornmental effectiveness of social programs, including but not limited to PES, by rigorously investigating the relative contributions of various mechanisms that incentivize agents to conserve. Our results also have important policy implications about the cost effectivenss of social programs with an environmental objective. For example, if the effect of contract dominates that of cash, a conditional cash transfer program could cost less by reducing the amount of cash paid out as long as a contract is signed and enforced.

Our work makes a second contribution to the limited but emerging literature that looks at the environmental outcomes of large-scale avoided deforestation programs. Using restrospective data, few studies have evaluated the effects of Mexico's program, and they are either limited in space (Honey-Roses, Baylis, and Ramirez 2011) or in time (Alix-Garcia, Shapiro, and Sims 2012)[2]. To date, the only research with avoided deforestation at the national level over time as an outcome has only been conducted for Costa Rica's program (see e.g. Arriagada et al. 2012; Robalino and Pfaff 2013) and Mexico's program (Alix-Garcia, Sims, and Yanez-Pagans 2015). In Brazil, the only paper that examines the effectiveness of a PES program on deforestation is one that evaluates a REDD+ pilot project implemented in the

[2]Honey-Roses, Baylis, and Ramirez (2011) evaluates Mexico's program in the Monarca reserve; Alix-Garcia, Shapiro, and Sims (2012) analyze the effectiveness of the program using only the 2004 cohort.

state of Para on 181 farmers (Simonet et al. 2015).Thus, to our knowledge, this paper is the first rigorous evaluation of a cash transfer program with an environmental conditionality on deforestation with spatial and temporal variation in the Brazilian Amazon.

The rest of the 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 different sources of data; Section 4 outlines the empirical strategy and discusses the estimation results; and Section 5 concludes.

2 Background

2.1 Deforestation in Brazil: 1960s to 2000s

The Brazilian Amazon hosts 40% of the world's tropical forests. When the local economy relied on extraction of forest resources in 1960s, Brazil implemented policies that encouraged the occupation of the Amazon. In the 2000s, however, government policies have been focused on reducing deforestation. In fact, the deforestation rate in 2014 is approximately 75% lower than the average from 1996 to 2005 (Tollefson 2015). Our study area is the Legal Amazon region, where the trends in deforestation are consistent with the national scale. As Figure 1 shows, total deforestation rate in the Legal Amazon from 2002 peaks in 2003 and has since then fallen annually. While there is a lack of concensus among economists as to what drives this large drop in deforestation in the mid-2000s, one of the popular views attributes this reduction to regulation efforts and conservation policies of the Brazilian Institute of Enviroment and Renewable Natural Resources (IBAMA) [3].

In this paper, we evaluate the Bolsa Verde program to study complementarities in conservation policies. The program is an initiative from the Brazilian government in 2011 to conserve and fight poverty in rural areas. With respect to Figure 1, Bolsa Verde is relevant for the period from 2011 to 2015, and for areas designated as priority areas, where the program is exclusively implemented. While the level of deforestation inside priority areas has always been low relative to the national average, deforestation activities that remain from 2011 onwards 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

[3] See, e.g. Gibbs, et al. (2015) and Nepstad, et al. (2014) for their analysis on the roles of interventions in the supply chain of soy and beef in reducing deforestation; Pfaff et al. (2014) and Assunção et al. (2015) for their evaluation of conservation policies as a driver of reduced deforestation; and Burgess et al. (2016), who analyze the power of the Brazilian state in shaping deforestation over time.

York City.

In addition to the level of deforestation inside priority areas, the upward trend in deforestation from 2012 onwards also raises concern, which, in part, motivates rigorous evaluations of programs like Bolsa Verde. Unlike areas outside priority areas where much of the deforestation is likely driven by economic activities of large landowners, whose contribution to deforestation has fallen by 63% since 2005, much of the deforestation inside are due to farmers with smallholdings, whose contribution to deforestation has increased by 69% (Godar et al. 2014). Against the somewhat rosy backdrop of large reductions in deforestation, policies that target the increasing deforestation acitivities of small-scale farmers and households, such as Bosla Verde, may become more important in sustaining the overall reductions in deforestation in the years to come.

2.2 Bolsa Verde: 2011 to Present

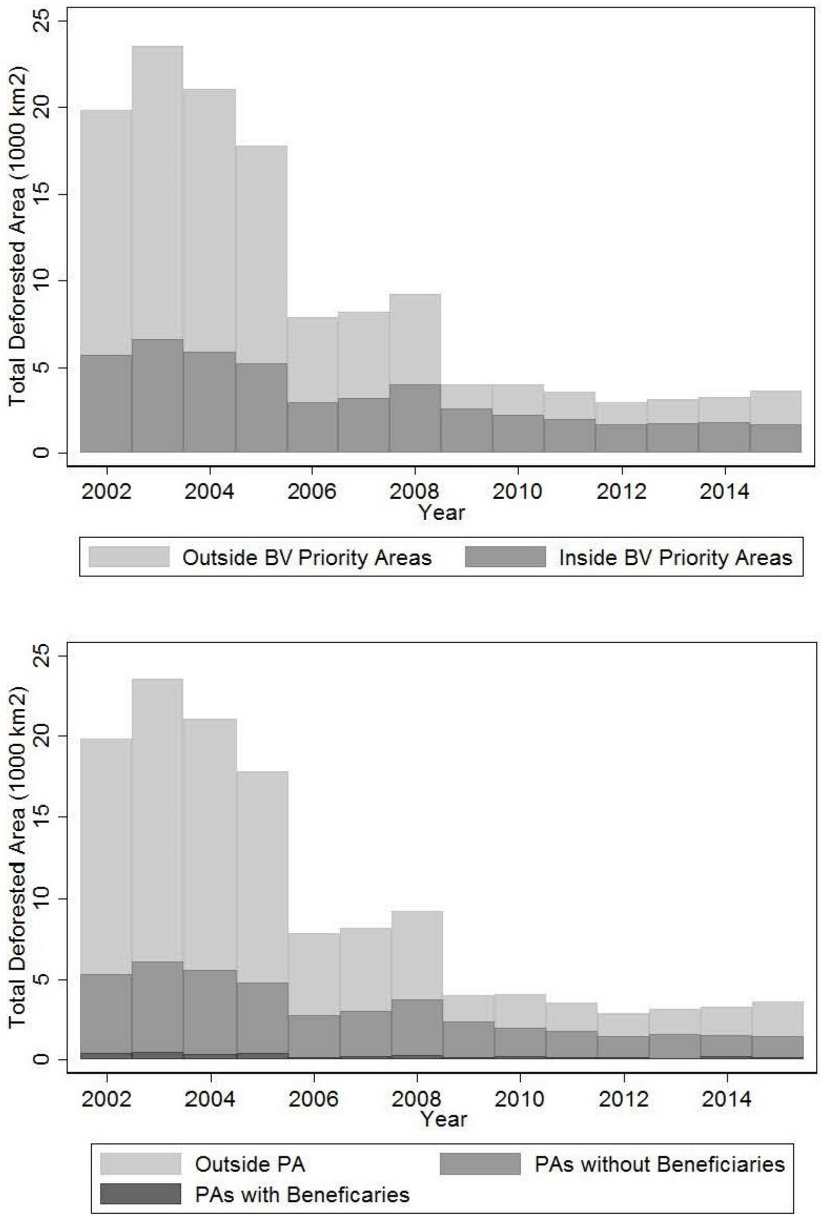
The motivation for the launch of Brazil's Bolsa Verde, the "Green Grant" program, is the recognition that 7.5 million people who live in extreme poverty, or almost half of the country's extremely poor, live in rural areas (Bindo 2012) [4]. By design, BV is a social program with dual objectives: to improve the livelihoods of poor households and to encourage enviornmental conservation. As requirements for being a BV beneficiary, a household should be (i) living in extreme poverty - defined as having per capita monthly income of under 77 reais (approximately 30USD); and (ii) living in a priority rural area, which has vegetation level that is in accordance with the Forest Code: at least 80% of the land is forested. Examples of priority areas defined by the program include categories within sustainable use conservation zones: the Extractive Federal Reserves (RESEX), the Sustainable Development Federal Reserves (RDS), and the Naitonal Forests (Flonas); Environmentally Distinctive Agraian Reform Settlements, managed by the National Institute of Colonization and Agricutural Reform (INCRA); as well as territories occupied by extractivists and indigenous groups[5].

The BV program was first implemented in 2011 and exlusively in priority areas within the Legal Amazon, covering an area that is approximately 61% of Brazil. The program has been expanded to priority areas in the rest of Brazil in 2012, with 64% of the program areas in the north, 26% in the northeast; 6% in the southeast; and 4% in the central-west (Bindo

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

[5]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.

Figure 1. Annual Deforestation from 2002 to 2015 in the Legal Amazon

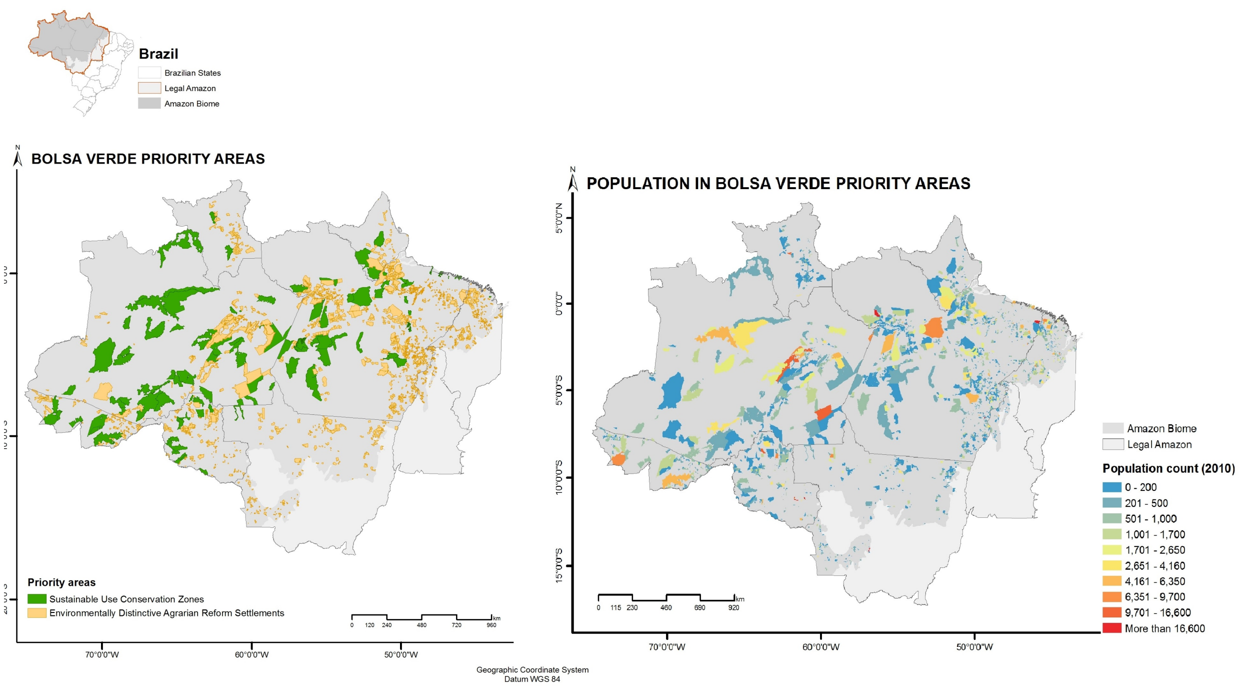


Note: Under the Bolsa Verde program, priority areas include the following categories of the sustainable use conservation zones: Flonas, RDS, and RESEX; indigenous lands; as well as the following categories within the Environmentally Distinctive Agrarian Reform Settlements: PA, PAE, PDS, and PAF.

Source: Authors' own calculations based on a list of Bolsa Verde recipients from the MMA and deforestation data from INPE.

2012). Figure 2, left panel, shows the spatial distribution of BV-eligible zones by category (Sustainable Use Conservation Zones in green and Settlements in orange) in our estimation sample, which is restricted to the Legal Amazon (in dark grey). The right panel demonstrates the population of these areas in 2010 based on the 2010 Census. On average, Settlements are more populated than conservation zones.

Figure 2. Bolsa Verde Priority Areas by Category and Population



In terms of entry into the program, the administrative process through which a BV-eligible household become a BV beneficiary has minimal selection. A list of households who are eligible for BV is sent to the Ministry of the Environment (MMA) for evaluation and fact checks. The majority of eligible households become beneficiaries because there are no selection criteria beyond the conditions that determine eligibility. Using data on all eligible households from 2011 to 2015 provided by the MMA, we calculate the proportion of eligible households and beneficiary households in each eligible area. Table 1 shows that, on average, the mean proportion of eligible households are the same as that of beneficaries. Moreover, the reasons for eligible households to be denied the grant, such as deaths of the responsible family member, missing signature, and incomplete forms, are likely exogenous with respect to deforestation and income levels.

An important feature of BV is that the only observable cost for an eligible household to become a beneficiary is the committment to maintaining the vegetation level in the zone where it resides. This committment is made in the form of a contract, or the "Terms of Adhesion," 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.

Upon signing this contract, BV beneficiaries receive quarterly payments in the sum of 300 reais for a period of up to two years, with the possibilty of renewal [6].

For our research design and estimation procedures, two elements of the BV program are crucial. First, BV is a cash transfer program with an envionromental conditionality, as opposed to being a PES. In other words, beneficiaries can exit the program even if activities that promote envionrmental conservation remain. One reason that prompts program exit is when the per capita household income no longer falls below the extreme poverty thresehold. Under a PES framework, households who become more well-off over time still receive payments for the ecosystem services they provide. Under the BV framework, however, the program's objective is to have fewer beneficiaries in subsequent years as their livelihoods gradually improve to the point where their income rises above the extreme poverty line.

A second reason for BV beneficiaries to exit the program is failure to adhere to the contractural terms. If the vegetation level of a zone falls below the pre-defined threshold, every BV beneficiary in the area exits the program. This exit prompt emphasizes the second characteristic of BV that influences our research design. Specifically, the fact that individual behavior relating to conservation within the priority area has consequences on all BV participants in the area suggests that BV provides incentives not only for individual conservation efforts but collective ones. We explore the various channels through which the BV program incentivizes conservation efforts, and derive the resulting predictions on deforestation and household behavior in our theoretical model [7].

3 The Data

3.1 Spatial Data on Deforestation

In this study, we use data on annual loss from primary forests and remaining forest cover in the Legal Amazon from the PRODES project at INPE, the Brazilian National Institute of Space Research [8]. The Legal Amazon is an area of 5,032 million km^2 that covers the northern and western parts of Brazil. Approximately 81% of the area is forested, 17% is

[6] Based on discussions with MMA officials, we find that renewal is a function of the availability of BV funds as well as meeting the income and vegetation requirments of BV. In other words, the continuous enrollment in BV after the initial two-year term has no implications on the zone nor the household beyond those from being eligible in BV the first time around.

[7] The theoretical mdoel is being developed and will be provided in later versions of the draft.

[8] 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.

cerrado (wooded grassland), and 1.8% 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 September in year t to August in year $t + 1$ [9]. We use data on deforestation in the period from 2009 to 2015, which brackets the few years before and after the launch of BV. In addition, we control for the initial conditions in deforestation prior to the BV program by calculating the stock of historical deforestation prior to and inclusive of 1997, as well as the deforestation that took place between 1997 and 2000. The satellite data used in PRODES have spatial resolutions of approximately 30 meters. We resample both the deforestation and remaining forest information from PRODES into 1 km^2 grid cells.

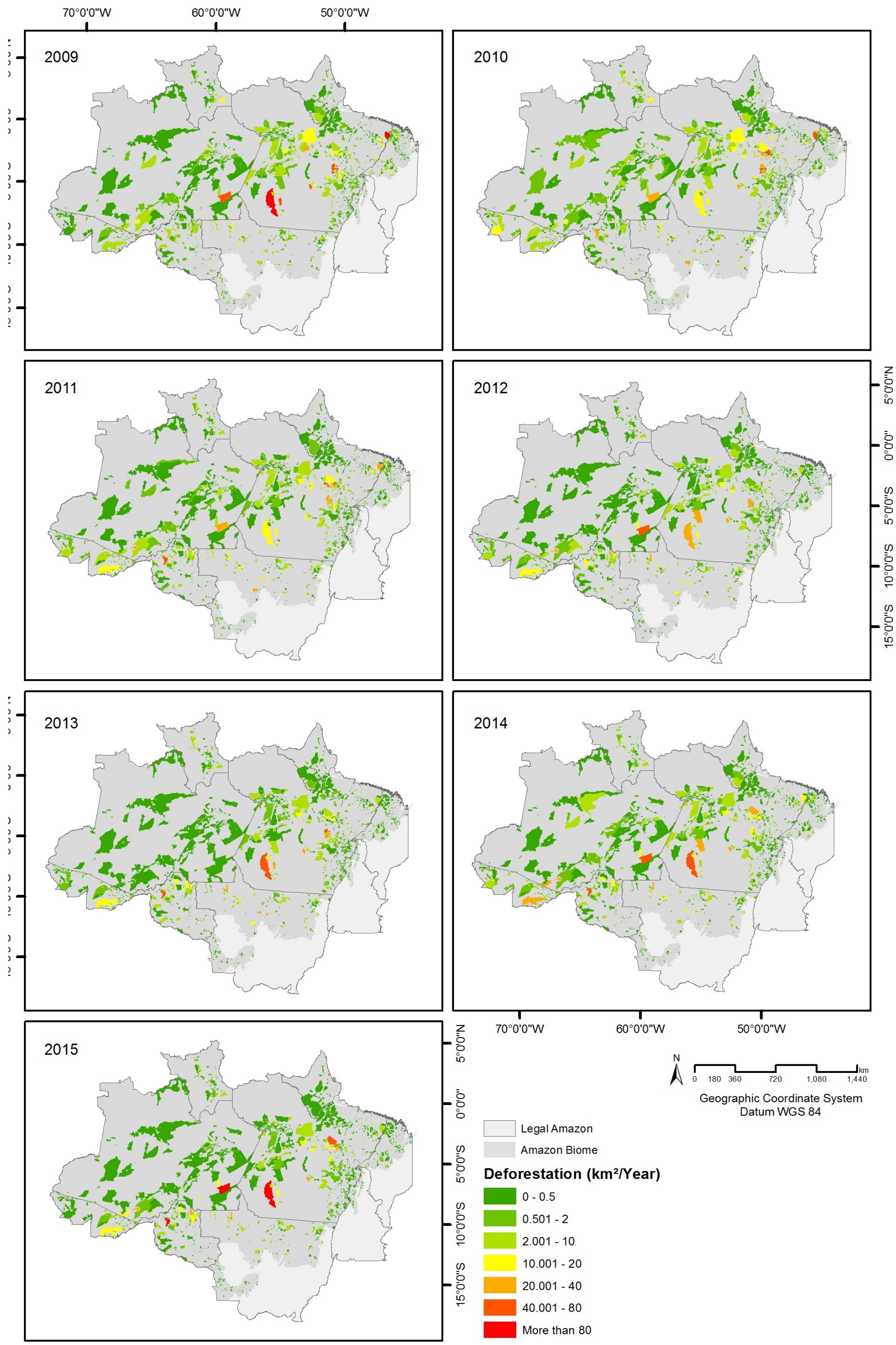
Figure 3 shows the levels of annual deforestation in BV-eligible areas from 2009 to 2015. We see that the colored areas are mostly green, that is the overall annual deforestation rate is consistently below 2.78 km^2 from 2009 to 2015. However, since the start of the BV program from 2012, we observe priority areas with increasing deforestation as they turn from green or light yellow to oragne or red. This change of color represents a change in deforestation from approximately 4.84 km^2 per year to over 73.86 km^2, a 15-fold increase. We also observe areas with decreasing deforestation, as shown by a change of color from yellow or orange to green. Our identification of the effect of the BV program draws from this variation in forest loss over time and across priority areas.

Using their centroids, we assign to each grid cell geo-specific information, such as distances to the nearest city, river, paved road, and political boundaries. Table 1 compares the eligible areas with and without BV beneficiaries across these geographic dimensions. In terms of general levels of economic development, we use the average satellite lights intensity from 2001 to 2010 as a crude proxy and we find that areas with BV beneficiaries are lit up at a higher intensity than otherwise. This result suggests that areas with BV recipients have higher initial levels of economic development on average than areas without BV beneficiaries prior to BV [10]. Since the BV program is only eligible for households living in extreme poverty, this comparison in average nighttime light intensity could also imply that areas with BV beneficiaries have higher levels of income inequality. In terms of initial levels of deforestation, areas with BV beneficiaries have 38% lower levels of deforestation (statistically significant at the 1% level). In terms of remaining forest, we find that these areas do have have sys-

[9]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.

[10]See Henderson et al. (2012) for a thorough discussion on the use of nighttime lights as a measure of economics growth.

Figure 3. Annual Deforestation Rates in Areas Eligible for Bolsa Verde (2009 to 2015)



tematically different stocks from 2009 to 2015, but the gap in the size of remaining forest has narrowed by 34% in 2015. This observation is consistent with the increasing trend in deforestation from 2012 onwards in Figure 1.

In terms of profitabilities of deforestation from other economic activities, such as logging, cattle ranching and sugarcane production, which depend partly on the access and cost of transportation to markets, we use distances to roads, rivers and cities as proxies. Neither type of areas have a dominant advantage over the other. While areas without BV beneficiaries are statistically closer to roads than areas with BV beneficiaries, they are further away from the nearest river and city. Having established that areas with and without BV beneficiaries are sysmatically different along dimensions other than participation in the BV program that could explain their differences in levels and trends in deforestation, we control for these priority area-level characteristics in our estimation model.

Table 1. Summary Statisstics of Priority Areas by Bolsa Verde Participation

	With BV Beneficiaries (A)	No BV Beneficiaries (B)	Test of Difference (A-B)
Time-Invariant characterstics			
Satellite Lights Intensity in the 1x1 km^2 cell#	0.450	0.182	0.268***
stock of historical deforestation up to 1997 (1 km^2)	14.496	22.705	-8.208***
stock deforestation between 1997 and 2000 (1 km^2)	2.405	4.777	-2.373***
distance to the Brazilian legal amazon	252,263.3	297,611.8	-44,979.48***
distance to the closest state boundary	105,682.6	103,093.8	2,588.748
distance to the closest municipality boundary	9,078.282	9,364.56	-286.278
distance to the nearest river	9,946.601	19,573.2	-9,626.603***
distance to the nearest road	19,525.59	10,397.04	9,128.55***
distance to the nearest city	30,669.94	34,297.57	-3,627.633***
Time-Varying characterstics			
stock of remaining forest (1 km^2): 2009	580.349	539.852	40.496
2010	579.898	538.836	41.062
2011	579.352	537.972	41.380
2012	578.953	537.270	41.683
2013	578.805	536.843	41.961
2014	578.805	536.843	41.961
2015	550.870	536.843	14.026

Note: # Number is an average over 2001 to 2010.

3.2 Household Data on Bolsa Verde Beneficiaries

To measure the presence and intensity of BV, we use information on beneficiaries from an exhaustive list of eligible households in all BV-eligible areas that we obtain from the MMA. The list includes all households who are eligible for BV from 2012 to 2015, containing information on the names of the representative household member, the priority area of residence, and the date of first BV cash receipt or the reason for rejection [11]. To evaluate the success of BV with respect to its enviornmental objective, we aggregate these data on BV-eligible households up to the priority area level to match with the deforestation data.

On average, approximately 60% of the population in priority areas are eligible for BV, implying that their monthly per-capita income fall below the extreme poverty line. Among those who are eligible, 67.9% of households become beneficiaries, who make up almost half of the total population in the priority area. Reasons for those who are eligible to be denied the BV grant include incorrect forms, missing signature, and other idiosyncratic errors in the application process that are uncorrelated with income level of the household or underlying propensities to deforest. Since there is no selection in the assignment of beneficiary status based on observed or unobserved household characteristics, we rule out concerns about endogeneity in the number of beneficiaries in each priority area. A majority of 82% of areas receiving BV payments are settlements, followed by 17% in Sustainable Use Conservation Zones. In our sample, of the 268 areas with households receiving BV payments by August 2015, 167 began receiving the grant by August 2012, while 43 additional areas enter the program by August 2013, 53 do so by August 2014, and 5 more areas begin receiving BV in 2015.

4 Estimation and Identification Strategy

In our empirical analysis, we restrict our sample to areas in the Legal Amazon region that are eligible for BV based on the administrative category. Some of these areas may have BV beneficiaries and some may not due to the income levels of households relative to the BV eligibility threshold. Our identification strategy relies on the variation in BV participation across space and over time, conditional on being a priority area eligible for BV. We begin with comparing the full sample of priority areas with BV beneficiaries against those without, regardless of the type of priority area. To address concerns that priority areas under different administrative categories may have sysmatically different preferences for deforestation, we also divide the sample into two categories: (1) sustainable use conservation zones that are ethier a FLONA, RESEX, or RDS); or (2) Environmentally Distinctive Agraian Reform Settlements.

[11] The list includes households who start receiving 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 recipients. Recall that deforestation is recorded from September to August of the following year. Thus, the first BV recipients from 2011 will be assigned to the deforestation rates in the year 2012 (September 2011 to August 2012).

4.1 Program Participation and Deforestation

Among areas that eventually have BV beneficiaries, some enter the program in 2012, some in 2013, others in 2014 and then more areas enter the program in 2015. To capture the spatial and temporal roll out of BV, we use the following generalized differences-in-differences framework to quantify the total impact of Bolsa Verde on deforestation:

$$Deforestation_{zt} = \alpha_0 + \beta BoslaVerde_{zt} + \alpha_1 Clouds_{zt} + \alpha_2 RemainingForests_{zt-1} + \nu_z + \mu_t + \epsilon_{zt}$$

where $Deforestation_{zt}$ is the amount of primary forest loss in priority area z between the periods t and $t-1$. We calculate the sum of forest loss across all the 1 km^2 grid cells whose centroids lie within a priority area [12]. $BolsaVerde$ is a dummy that equals one if the area z has residing households that receive BV payments in year t. Our coefficient of interest is β, which is the difference-in-differences estimate of the average treatment effect of Bolsa Verde on deforestation in the treated priority areas. Our specification includes other factors at the priority area and year levels that could impact deforestation, including $Clouds$, which denotes the proportion of clouds in a priority area; $RemainingForests$, which denotes the stock of remaining forests in an area in the previous year, as well as the interaction of lagged remaining forests stock and distances to the nearest paved road. We also include priority area fixed effects and year fixed effects to control for any overall differences in deforestation between priority areas with and without BV beneficiaries. We cluster standard errors at the priority area levels to control for arbitrary spatial and serial correlation. Table 2 reports the estimated treatment effect of BV, β, in the different specifications.

The key result is that we do not find an overall effect of BV on deforestation, but if we estimate the program impact on conservation zones and settlements separately, we find effects in the former: BV reduces deforestation. Column 6 reports the preferred specification, which shows that BV is associated with 0.94 km^2 per year less deforestation, a reduction of 76% compared to the pre-BV average (significant at the 5% level). In Settlements, we estimate a statistically insignificant effect of 0.051 km^2 per year reduction in forest loss, which amounts to 20% of the pre-program average (column 9). Identification in our difference-in-differences analysis so far draws from the variation in deforestation rates over time within BV-areas versus within non-BV areas. Thus, the validity of the estimate relies on the assumption that these two types of areas do not have systematically different trends in deforestation in the absence of BV, controlling for remaining forest, year and priority area fixed characteristics.

[12] 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 2. Total Impact of Bolsa Verde Participation on Deforestation

	Annual Total Deforested Area (km^2)								
	All Priority Areas			Conservation Zones			Agrarian Settlements		
x=participation in Bolsa Verde (0/1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Whole sample	0.0261	-0.0242	-0.0299	-0.725*	-0.654*	-0.826*	-0.0554	-0.0548	-0.0513
	(0.0930)	(0.0956)	(0.0972)	(0.389)	(0.391)	(0.445)	(0.0951)	(0.0915)	(0.0932)
Pre-BV mean deforestation		0.384			1.115			0.251	
% change in deforestation	…	…	…	-65.022	-58.655	-74.081	…	…	…
Observations	12,841	12,841	12,841	606	606	606	12,235	12,235	12,235
R^2	0.055	0.084	0.084	0.258	0.263	0.282	0.158	0.172	0.172
Clean sample	0.0238	-0.0311	-0.0368	-0.833**	-0.754*	-0.937**	-0.0540	-0.0542	-0.0506
	(0.0970)	(0.101)	(0.102)	(0.409)	(0.413)	(0.467)	(0.0992)	(0.0957)	(0.0972)
Pre-BV mean deforestation		0.404			1.239			0.257	
% change in deforestation	…	…	…	-67.232	-60.856	-0.756	…	…	…
Observations	12,701	12,701	12,701	571	571	571	12,130	12,130	12,130
R^2	0.055	0.084	0.084	0.260	0.264	0.283	0.158	0.172	0.173
Control variables:									
Lagged remaining forests*distance to paved roads	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Lagged remaining forests*distance to cities	No	No	Yes	No	No	Yes	No	No	Yes

Note: Robust standard errors clustered at the priority area level in parenthesis. All models include priority area and year fixed effects. Controls include clouds and lagged remaining forests in all specfications. Clean sample exlucdes priority areas with fewer than 4 recipients (bottom 5% of the distribution) of BV reipients at the maximum. *** p<0.01, ** p<0.05, * p<0.10

Table 3 tests for the presence of differential pre-trends by interacting future BV status with the time trend using data from 2002 to 2011. Using the full sample, we do not find significant differences in the annual mean deforestation rate between the two types of areas prior to the launch of BV, suggesting that in absence of BV, the expected levels of deforestation should remain parallel after 2011.

Table 3. Parallel Trend Test in Pre-Bolsa Verde Deforestation from 2002 to 2011

Dependent Variable: Annual Deforested Area	All Eligible Areas	Conservation Zones	Settlements
Future benefiary status x Year	-0.0229	-0.397	-0.0442
	(0.0701)	(0.702)	(0.0654)
Lagged remaining forest	0.457***	0.645*	0.422***
	(0.0949)	(0.346)	(0.0733)
Priority Area FE	Yes	Yes	Yes
State x Year FE	Yes	Yes	Yes
Observations	5,502	252	5,250
R^2	0.415	0.455	0.433

Note: Robust standard errors clustered at priority area level in parenthesis. All specifications control for clouds.
*** p<0.01, ** p<0.05, * p<0.10

4.2 Spillover Effects

For robustness, we use grid cell-level data from 2009 to 2015 to generate regression discontinuity figures to explore causal effects of BV on deforestation at the priority area border. For each grid cell, we calculate the distance to the nearest border of a receiving BV priority area. In the sample, we exclude cells that are outside any eligible BV priority area. Therefore, all cells outside and are plotted below lie inside a non-receiving but eligible priority area. We limit our plots to 10 kilometers outside and inside the borders. We impose the number of bins to be 15 on each side of the border, and we impose a first order polynomial fit. Figure 4 plots the deforestation of cells inside and outside BV-receiving Sustainable Conservation Zones and Figure 5 plots the equivalent insisde and outside BV-receiving Settlements.

We observe that prior to the BV program, cells inside and outside conservation zones exhibit a continuous trend across the border, but display a reduction in the level of deforestation at the border after the zone has started receiving BV payments. This pattern is consistent with the result we obtain in the zone-level regressions reported in Table 3. Although we observe a reduction in the levels of deforestation at the border after the BV program in Settlements, we do not observe continuity across the border prior to BV. Therefore, we cannot conclude a causal relationship between BV and the reduction in deforestation in Settlements, consistent with the regression results.

Figure 4. Deforestation Inside and Outside BV-Receiving Sustainable Use Conservation Zones

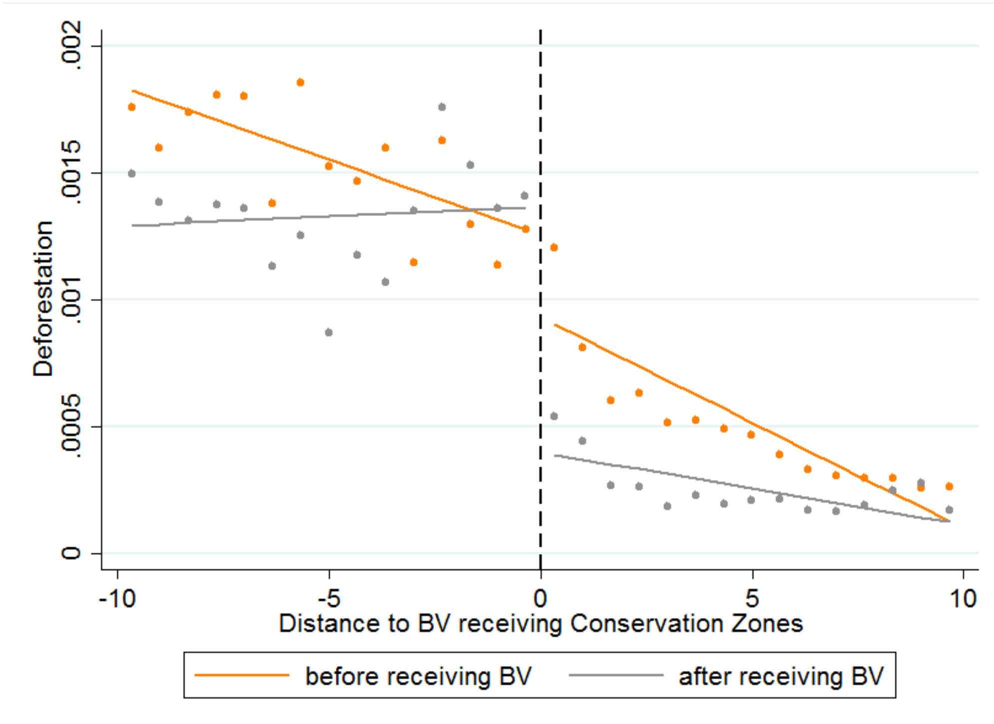
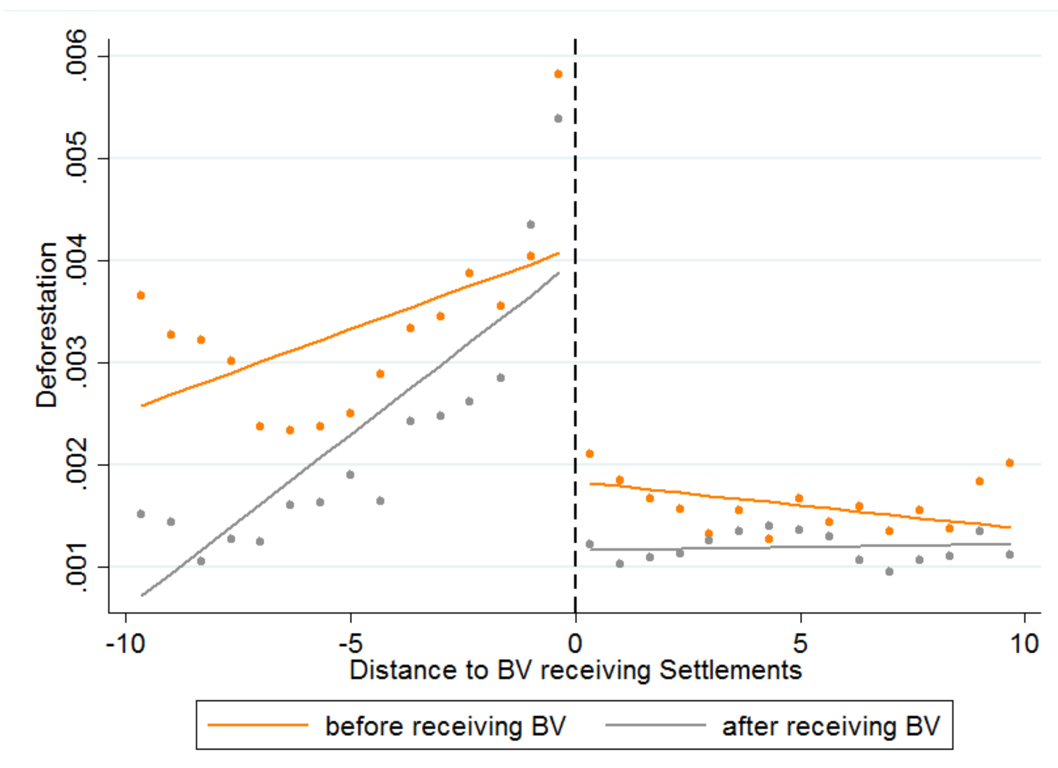


Figure 5. Deforestation Inside and Outside BV-Receiving Settlements



4.3 Program Intensity and Deforestation

Next, we explore the association between the intensity of the BV program and deforestation. Our prior is that the effect of BV on deforestation is larger in areas with a higher share of the population receiving the BV grant. This conjecture is based on the design of BV, which requires beneficiaries to commit, via a contract, to preserving the vegetation level of the priority area. This contractural term contrasts with the environmental conditions in the majority of payments for ecosystem services schemes, such as Mexico's Payments for Hydological Services Progam (PSAH), where landowners commit to conserving only the pieces of land they own [13]. Under the BV program, eligibility is partly based on the level of vegetation in the entire priority area where they reside instead of specific parcels of land. BV beneficiaries are not necessarily landowners, and the commitment made via the contract implies that individual behavior that alter vegetation levels within the priority area has consequences on all BV beneficiaries. If one of the channels through which areas with BV beneficiaries have less deforestation is through a monitoring effect, by which beneficiaries report or stop illegal clearing of land they observe, then we expect this monitoring effect to be positively correlated with the share of BV beneficiaries in the priority area population.

We repeat the estimaton of equation (1) by using the number of BV beneficiaries in a priority area at time t as the dependent variable. We report the results in Table 4, which shows that the number of recipients in a priority area is important for how effective the program is in reducing deforestation. Column 6 shows that an additional BV recipient in Sustainable Use Conservation Zones is associated with 0.0028 km^2 less forest loss per year. The estimated coefficient is negative in Settlements, but it is of smaller magnitude and is statistically insignificant. Given the total number of 7,798 BV recipients in conservation zones in our analysis sample, this result implies that scaling up BV in these areas by doubling its demographic coverage translates into an additional 21.8 km^2 less deforestation per year.

4.4 Mechanism: Financial Incentives

In this section, we explore the mechanisms through which BV has a distinct effect on deforestation. First, we hypothesize that the cash payment of BV provides financial incentives for compliance with the contract to maintain forest cover in the priority area of residence. If this was the case, we would expect that BV has a higher impact on deforestation in

[13] In Mexico's PSAH, landowners enroll parcels of land they own and agree to conserve the forest cover on the enrolled parcels. See Alix-Garcia et al. (2015) for details of the program.

Table 4. Total Impact of the Number of Bolsa Verde Recipients on Deforestation

	Annual Total Deforested Area (km^2)								
	All Priority Areas			Conservation Zones			Agrarian Settlements		
x=number of recipients	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Whole sample	-0.000344	-0.000580	-0.000579	-0.00227	-0.00210*	-0.00278**	-0.000432	-0.000414	-0.000411
	(0.000471)	(0.000570)	(0.000573)	(0.00137)	(0.00110)	(0.00137)	(0.000549)	(0.000561)	(0.000558)
Pre-BV mean deforestation		0.384			1.115			0.251	
% change in deforestation	…	…	…	…	-0.188	-0.249	…	…	…
Observations	12,841	12,841	12,841	606	606	606	12,235	12,235	12,235
R^2	0.055	0.084	0.084	0.260	0.264	0.285	0.158	0.172	0.172
Clean sample	-0.000343	-0.000579	-0.000578	-0.00223	-0.00207*	-0.00276**	-0.000433	-0.000415	-0.000412
	(0.000471)	(0.000571)	(0.000574)	(0.00136)	(0.00110)	(0.00138)	(0.000557)	(0.000569)	(0.000566)
Pre-BV mean deforestation		0.404			1.239			0.257	
% change in deforestation	…	…	…	…	-0.167	-0.223	…	…	…
Observations	12,701	12,701	12,701	571	571	571	12,130	12,130	12,130
R^2	0.055	0.084	0.084	0.261	0.265	0.286	0.159	0.173	0.173
Control variables:									
Lagged remaining forests*distance to paved roads	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Lagged remaining forests*distance to cities	No	No	Yes	No	No	Yes	No	No	Yes

Note: Robust standard errors clustered at the priority area level in parenthesis. All models include priority area and year fixed effects. Controls include clouds and lagged remaining forests in all specfications. Clean sample exlucdes priority areas with fewer than 4 recipients (bottom 5% of the distribution) of BV reipients at the maximum. *** p<0.01, ** p<0.05, * p<0.10

poorer priority areas than in wealthier ones. Priority areas are divided into poverty groups using monthly per capita household income from CadUnico (the single registry), managed by Brazil's Ministry of Social Development (MDS). The registry has detailed demographic and socio-economic information on all households and its members who are under any social program in Brazil, including Bolsa Verde. *Non poor* priority areas are defined as those with more than 50% of BV receiving households with per capita monthly household income at or above the 75th percentile of the 77 Reais income eligibility threshold (more than 57.75 Reais); *poor* priority areas are defined as those with more than 50% of BV receiving households with per capita monthly household income bwtween the 25th and 75th percentile of the 77 Reais income eligibility threshold (between 19.25 and 57.75 Reais); *extremely poor* priority areas are defined as those with more than 50% of BV receiving households with per capita monthly household income below the 25th percentile of the 77 Reais income eligibility threshold (fewer than 19.25 Reais). Reported coefficients are interactions of the number of BV reicipients and the poverty category dummies. The regressions control for clouds, lagged remaining forests, interactions between lagged remaining forests and distances to paved roads as well as distances to cities. All models include year and priority area fixed effects

Table 5 reports the estimated impact of BV on deforestation at the three categories of poverty at the priority year level. We find that the impact of an additional BV recipient on deforestation is statistically the same in extremely poor, poor and non poor priority areas (we cannot reject that that coefficiensts are identifical). This suggests that financial incentives are not the main drivers of compliance with BV.These results should be interpreted with caution because we only have the income of recieving BV households at the prioirty area level. Therefore, what follows below is not a true difference in differences framework, because we are unable to compare similarly poor priority areas wtih and without BV recipients. Instead, what has been done is to essentially compare the before and after deforestation levels among BV receiving priority areas of similar poverty levels.

4.5 Mechanism: Social Incentives

We also hypothesize that the BV contract provides social incentives for compliance with BV. Recall that BV recipients, as a group, risk losing payments if the forest cover in the priority area no longer complies with the Forest Code (80% of forests). Therefore, there might be social incentives for recipients to collectively maintain the forest cover. First, recipients may engage in colletive conservation activities, which we do not observe. Second, recipients may monitor each other's deforestation behavior and possibly report to the authorities (IBAMA or ICMBio) if they witness illegal activities. More monitoring and/or the threat of reporting is expected to reduce deforestation. Both the strengh of monitoring and the threat of reporting are unobserved. Third, more reports may reduce or increase deforesation (more reports may discourage future deforestation; more reports may also be correlated with more future deforestation if the fines are low relative to profits from deforestation).

Although we do not have a measure of group monitoring or reports made to IBAMA or ICMBio, we have a time-series dataset on infractions (fines issued against illegal deforestation activities). In each BV-eligible priority area, we calculate the total number of infractions that lie inside their boundaries in each year. Figure 6 shows that these infractions go up over time in both receiving and non-receiving priority areas. An increase in these infractions over time maybe due to a number of reasons: (i) more reporting (ii) more deforestation (iii) more government enforcement, or a combination of the above; a decrease in the number of infractions over time may reflect lower deforestation due to (iv) stronger monitoring. Figure 7 shows that, indeed, deforestation and infractions are positively correlated. However, we can rule out reason (ii) because Figure 8 shows that in both receiving and non-receiving areas, deforestation has a downward-sloping trend in the same period.

If we find that BV participation increases the number of infractions, which in turn decreases future deforestation, then we can verify reason (i), reporting, as a mechanism ex-

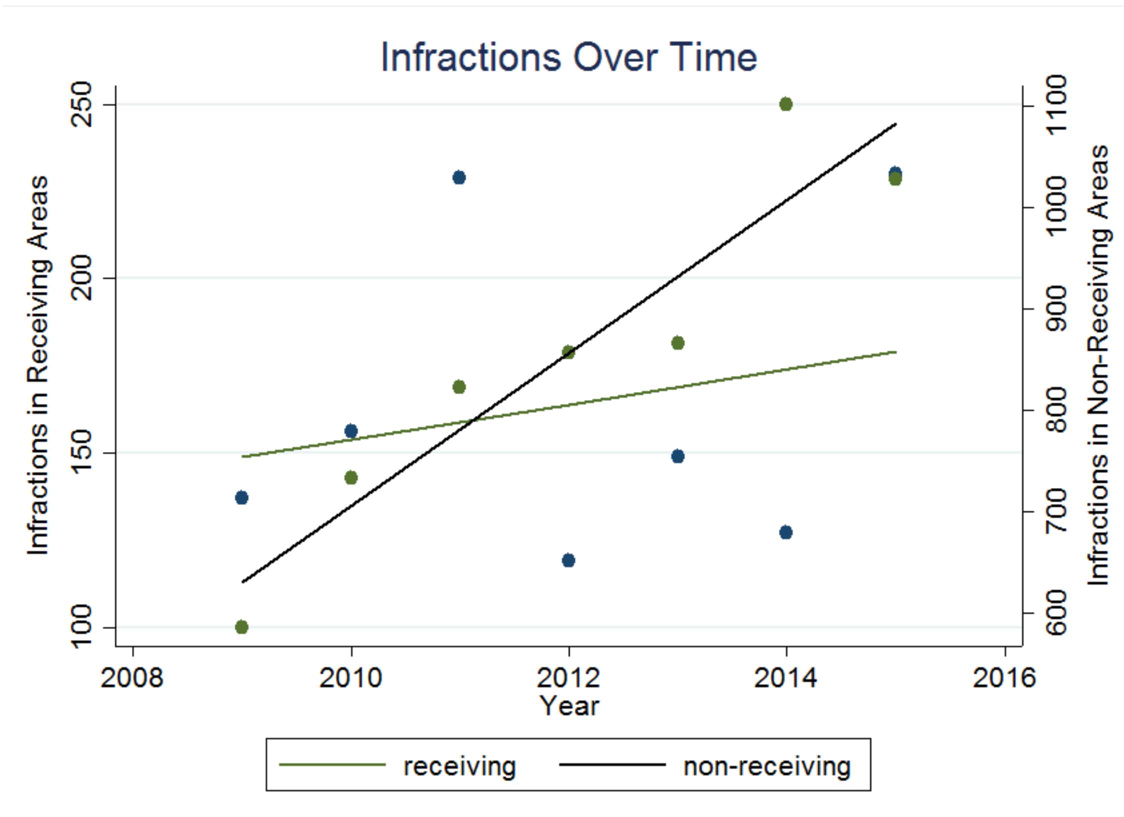
Table 5. Total Impact of the Number of Bolsa Verde Recipients on Deforestation

	Annual Total Deforested Area (km^2)								
	All Priority Areas			Conservation Zones			Agrarian Settlements		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Estimated Impact Coefficients	Pre-BV Mean Deforestation	% Change in Deforestation	Estimated Impact Coefficients	Pre-BV Mean Deforestation	% Change in Deforestation	Estimated Impact Coefficients	Pre-BV Mean Deforestation	% Change in Deforestation
extremely poor priority areas	-0.00102**	0.401	-0.25	-0.000427	1.167	…	-0.000926*	0.213	-0.43
	(0.000506)	[163]		(0.000781)	[32]		(0.000511)	[131]	
poor priority areas	-0.00128***	0.404	-0.32	-0.00268**	1.227	-0.22	-0.000883**	0.266	-0.33
	(0.000330)	[480]		(0.00121)	[69]		(0.000390)	[411]	
nonpoor priority areas	-0.000909***	0.18	-0.51	0.000937	0.501	…	-0.000676***	0.142	-0.48
	(0.000193)	[47]		(0.00387)	[5]		(0.000223)	[42]	
F test: non-poor = poor = extremely poor	0.73			1.37			0.30		
	(0.484)			(0.269)			(0.742)		
Observations	1,862			294			1,568		
R^2	0.138			0.287			0.192		

Note: Priority areas are divided into poverty groups using monthly per capita household income from CadUnico (MDS). Non poor priority areas are defined as those with more than 50% of BV receiving households with per capita monthly household in at or above the 75th percentile of the 77 Reais income eligibility threshold (more than 57.75 Reails); poor priority areas are defined as those with more than 50% of BV receiving households with per capita monthly household income between the 25th and 75th percentile of the 77 Reais income eligibility threshold (between 19.25 and 57.75 Reails); extremely poor priority areas are defined as those with more than 50% of BV receiving households with per capita monthly household income be the 25th percentile of the 77 Reais income eligibility threshold (fewer than 19.25 Reails). Reported coefficients are interactions of the number of BV reicipients and the poverty category dummies. The regressions control for clouds, lagged remaining for interactions between lagged remaining forests and distances to paved roads as well as distances to cities. All models include year and priority area fixed effects. Robust standard errors clustered at the municipality levels are in parenthesis.

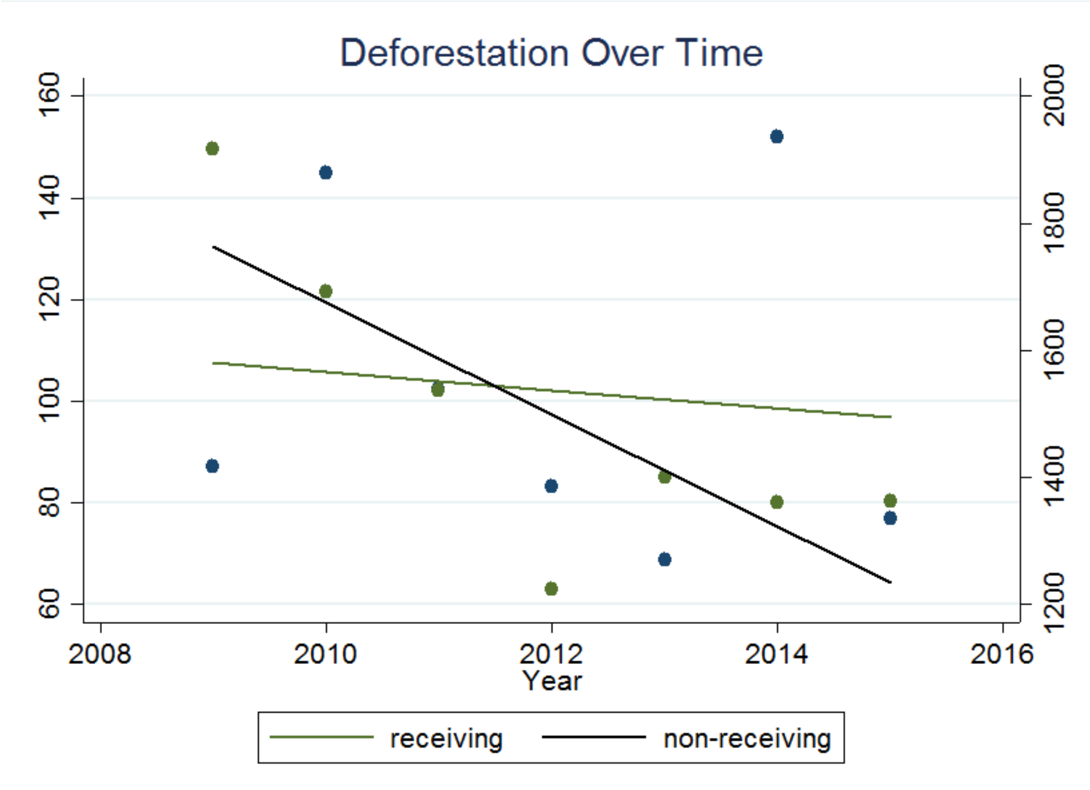
plaining the estimated impact of BV. If we find that BV decreases the number of infractions, which is a function of deforestation, then the result suggests that reason (iv), monitoring, maybe a mechanism. This would also be consistent with our finding that the higher the number of BV recipients, the higher the reduction in deforestation. However, we cannot rule out that this result may also be partly driven by reason (iii), the government enforcement channel, if BV is correlated with more enforcement effort by the government in receiving areas.

Figure 6. Number of Infractions by BV-Receiving Status



In addition, the result may also be partly driven by an additional channel, which is information (v): the presence of the BV program signals to recipients that their priority areas will be watched more intenstively by the agencies (but in reality enforcement effort may be unchanged). This information may have led to less deforestation due to an expected increase in the risk of getting caught. Table 6 reports estimated coefficients of a model where we regress the deforestation at time t on the total number of infractions in an area at time $t-1$. We find that BV reduces infractions, which in turn are positively correlated with future deforestation. Therefore, we can rule out reason (iii). The result is also consistent with that on deforestation. Therefore, reason (iv) seems to be valid. However, given that

Figure 6. Annual Deforestation Rates by BV-Receiving Status



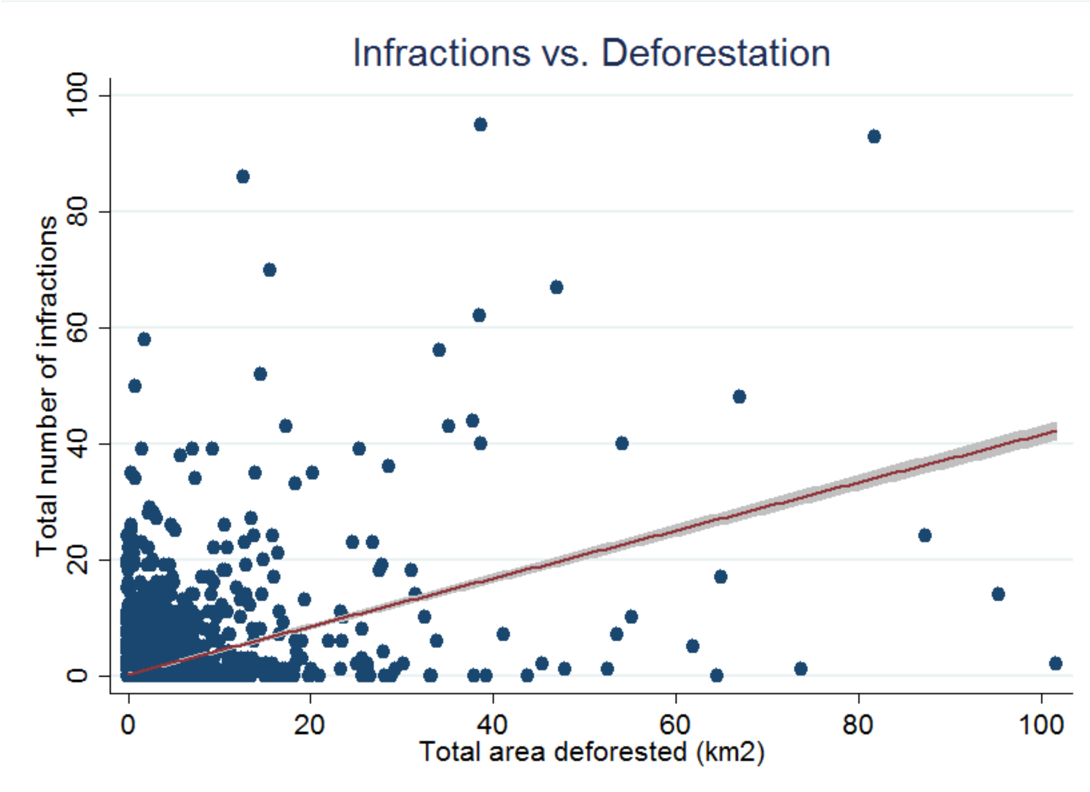
reason (iv) maybe coupled with reasons (iii) and (v), our estimate of a social channel may be overestimated.

5 Conclusion

It is of policy relevance to understand what incentives are important in driving the desired behavioral outcome in the target population. We study Brazil's Bolsa Verde program as a case study to explore whether the financial and social incentives provided by the program are effective in reducing deforestation. Our research strategy takes advantage of the unique design of the program, which entails a quarterly cash grant and signing of a one-time contract. The contract specifies that the grant is conditional on maintaining the regional vegetation level, implying that deforestation in any part of the priority area creates negative externality on all BV beneficiaries.

Our main finding is that at the priority area level, BV reduces deforestation: the average treatment effect on the treated is 76% of pre-program mean. The number of beneficiaries also matter: an additional BV recipient in Sustainable Use Conservation Zones is associated

Figure 8. Annual Deforestation Rates by BV-Receiving Status



with 0.0028 km^2 less forest loss per year. This result implies that a possible mechanism for the effectiveness of BV is the group liability feature in BV contracts, which induce group monitoring. We also show that financial incentives do not drive the success of BV, which is equally effective in relatively poorer and nonpoor areas. Our study highlights the importance of incentivizing collective action in maintaining forest cover. While the theory behind the use of cash grants in reducing deforestation by compensating forgone revenue or rewarding forest-preserving behavior is unambiguous (see e.g. Engel, Pagiola, and Wunder 2008; Jayachandran 2013), the link between contract and reductions in deforestation is not. Whether the BV contract reduces deforestation by incentivizing households not to deforest themselves, or by encouraging monitoring at a group level, or through a combination of both channels, remains open for future research.

Table 6. Total Impact of the Number of Bolsa Verde Recipients on Deforestation

	All Priority Areas			Conservation Zones			Agrarian Settlements		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Total Number of Infractions		Annual Total Deforested Area (km^2)	Total Number of Infractions		Annual Total Deforested Area (km^2)	Total Number of Infractions		Annual Total Deforested Area (km^2)
treatment (BV participation)	-0.374*			-0.259			-0.629		
	(0.209)			(0.304)			(0.468)		
treatment (number of BV recipients)		-0.000934***			-0.000600			-0.00136**	
		(0.000358)			(0.000385)			(0.000596)	
number of infractions at t-1			0.127***			0.179			0.100***
			(0.0289)			(0.148)			(0.0290)
number of infractions at t-2			0.117***			0.192			0.109***
			(0.0309)			(0.212)			(0.0339)
Observations	11,002		9,166	514		428	10,488		8,738
R^2			0.115			0.228			0.169

Note: Robust standard errors clustered at the municipality level in parenthesis. All models include year fixed effects. Specifications with total number of infractions as the dependent variable are estimated using the zero inflated poisson regression, with lagged remaining forests as the predictor for excess zeroes. Specifications with deforestation as the dependent variable include year and priority year fixed effects.
Controls include clouds and lagged remaining forests in all specfications. *** p<0.01, ** p<0.05, * p<0.10.

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